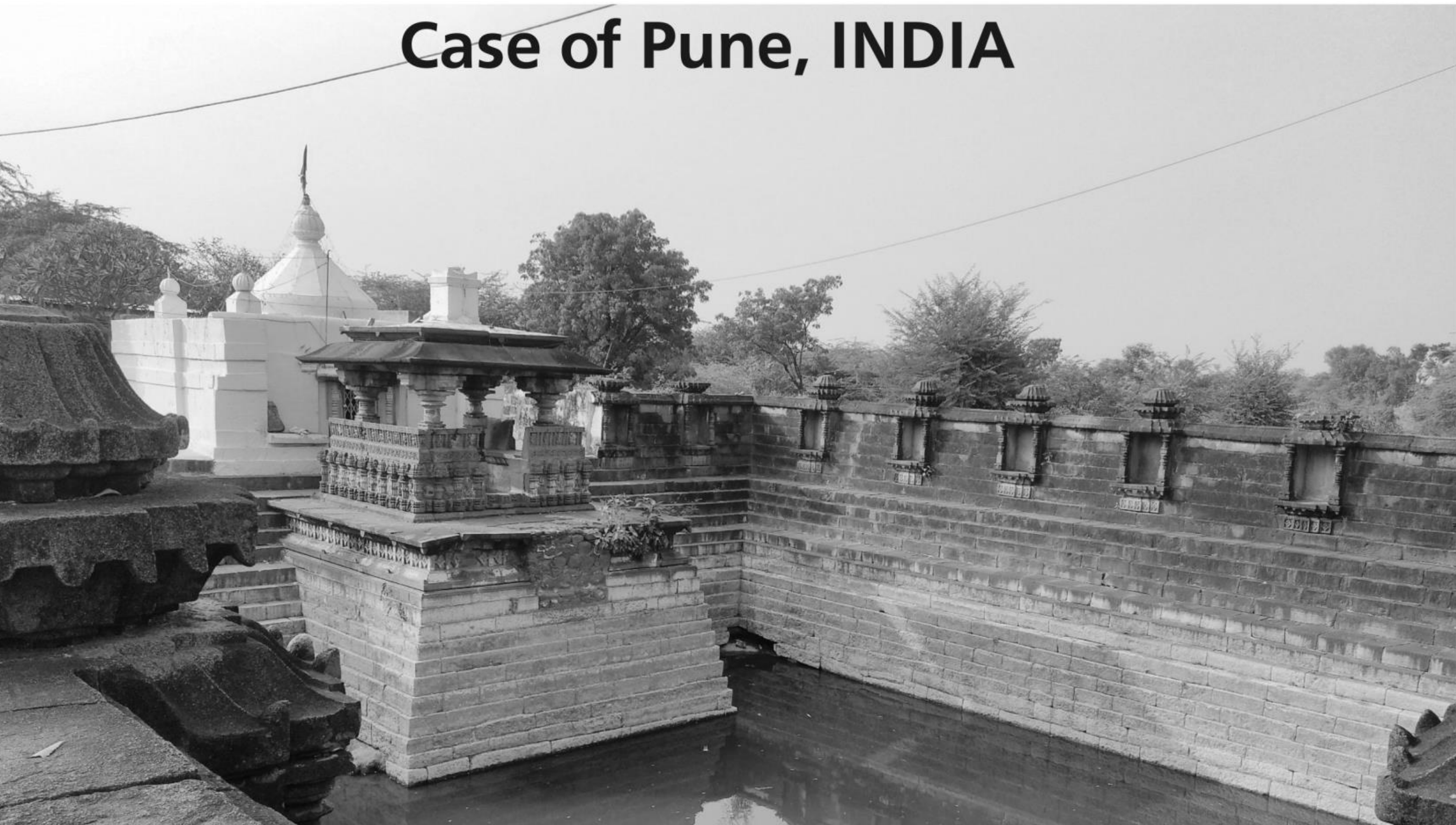
Reimagining Water Infrastructure in its Cultural Specificity

Case of Pune, INDIA



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REIMAGINING WATER INFRASTRUCTURE IN ITS CULTURAL SPECIFICITY
Case of Pune, INDIA.

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Erklärung zur Dissertation

Hiermit versichere ich, die vorliegende Dissertation ohne Hilfe Dritter nur mit den angegebenen Quellen und Hilfsmitteln angefertigt zu haben. Alle Stellen, die aus Quellen entnommen wurden, sind als solche kenntlich gemacht. Diese Arbeit hat in gleicher oder ähnlicher Form noch keiner Prüfungsbehörde vorgelegen.

Darmstadt, den 11-09-2019.

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(Manas Rajendra Marathe)

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Abstract

Depleting water sources, rapid urbanisation and extreme human intervention in the ecological cycles leading to climate change exert intense pressure on the water infrastructure of several regions across the world. At the same time, design of current water infrastructure itself based on the post-industrial principle of controlling nature using modern technology has given rise to additional problems such as land subsidence, transformation of rivers, depletion of groundwater, human displacement and loss of biodiversity. In industrialising countries such as India, increasing population puts additional pressure on the finite internal water sources. The per capita water availability in India is expected to fall from current 1608 m^3 to 1340 m^3 by 2025, causing water stress conditions. There is limited scope for exploring additional water sources. Already with more than 5000 large dams and 11.7 million tubewells, India has the highest annual freshwater usage in the world.

Against the background of these multiple and interconnected water problems worldwide and in India, the research on water infrastructure design and management suggests the need to bring about a fundamental change in the way we perceive water, and manage and design our water infrastructure. It recommends the need to shift away from the modern approach that views water as a commodity and develops water infrastructure that concentrates on maximum exploitation of natural water sources through command and control over nature. Instead, it proposes a sustainable approach that causes minimum disturbance to the natural hydrological cycle, attempts to manage freshwater demand in the society and concentrates on rainwater harvesting and wastewater recycling. Particularly in the case of India, research recommends the need to revive its traditional knowledge of water management and conserve the structures that diverted, stored and utilised surface-runoff, rainwater and groundwater in a sustainable manner.

The current research on traditional water structures in India extensively focusses on their technical and managerial aspects. In comparison, less research focusses on their spatial aspect and form that integrate them with the settlement fabric. Furthermore, many research approaches take a mere overview of diverse water structures across India. However, very few approaches discuss in depth the socio-cultural setup within which they flourished, the reasons for their decline, and their significance in the present context. To overcome these research gaps, this research undertakes a socio-cultural perspective on understanding the value of Traditional Water Infrastructure (TWI) in creating water consciousness and reimagining water infrastructure creatively. Taking the case of Pune, India, it first examines how cultural beliefs and ideas have shaped its TWI. Then, through the case examples of traditional water cisterns, stepped water tanks, underground aqueducts and artificial lakes in Pune, it sheds light on the spatial and architectural principles of TWI. It further examines the reason for their decline during the British Colonial and Post-Colonial Periods and highlights their role in solving current water-related problems.

The research presents data obtained through the review of secondary literature and archival records carried during February and September 2017. Similarly, it presents data from field observations, photographic documentation and measured drawings done during February-March 2018 and November-December 2018. The findings reveal that the limited availability of water due to the intermittent nature of rivers and the monsoon pattern created a conscious water culture in the traditional communities that encouraged people to use water prudently. The values, beliefs and ideas emerging from such culture have shaped the TWI of Pune. The traditional water structures were location-specific and built through people's participation and the patronage of rulers. They were not only mere utilitarian structures but also places for public gathering, interaction and performing daily rituals.

However, in spite of its critical role in sustainable water management, TWI experienced a gradual decline during the British-Colonial and Post-Colonial Periods. The British interference in the socio-cultural life patterns of people and a lack of patronage for constructing and maintaining water structures compelled the people to give up TWI gradually and rely on the modern infrastructure of dams and canals. Even after independence, the endeavour of Indian nationalists to portray India as a modern and progressive nation made them focus on the expansion of centralised water infrastructure and neglect TWI. At the same time, rapid demographic and spatial growth of Pune increased its water demand. Therefore, for finding quick-fix solutions to increased water demand, the technology of extracting groundwater by tubewells became popular. Thus, irrespective of the unsustainability of modern water infrastructure, its convenience of obtaining water easily without much effort instigated many people to give up TWI.

In light of the above findings, the research infers that the resurfacing of traditional knowledge about water management is essential for bringing back water consciousness in the society. Similarly, learning from TWI would aid us to reimagine and design our future water infrastructure in a sustainable manner. In conclusion, the research recommends four ways in which TWI could assist in solving water-related problems and improving the quality of our environment. Firstly, repairing the existing TWI and designing similar smaller water storage structures in future would make water sources diverse. Accessing diverse water sources rather than a single centralised water source would make water supply more resilient to failures due to natural calamities. Secondly, TWI within urban and peri-urban areas could function as urban sponges storing rainwater and preventing excessive surface runoff. Thirdly, protecting TWI and small water bodies would maintain the biodiversity in nature, as they are the natural habitats for some rare species of flora and fauna. Additionally, the presence of TWI within urban areas would help in dropping their surface temperatures significantly through evaporative cooling, thereby reducing the heat-island effect. Lastly, water structures enabling people to see and experience natural water could function as vibrant public places, pause points and visual landmarks within the settlement fabric.

With these conclusions and recommendations, the research suggests that in future, we cannot solve water-related problems by attempting to gain command and control over nature and the use of technology alone. Instead, it is necessary to accept that most of the problems are human-created, and they could be solved only with the correction in human action and human perception of water.

Keywords: traditional water infrastructure, culture, Pune, India

Zusammenfassung

Extreme menschliche Eingriffe in ökologische Kreisläufe, die zum Klimawandel, nachlassenden Wasserressourcen und beschleunigter Urbanisierung führen, üben großen Druck auf die Wasserinfrastruktur vieler Regionen der Welt aus. Zur selben Zeit begünstigt das Design dieser Infrastrukturen, das selbst vom postindustriellen Prinzip der Naturbeherrschung durch moderne Technik durchdrungen ist, die Verschärfung weiterer Entwicklungen, wie etwa Landabsenkung, Flusstransformation, Grundwasserknappheit, Massenvertreibungen und Verlust der Biodiversität. Zusätzlich erhöht die steigende Population in Schwellenländern wie Indien weiter den Druck auf knappe Wasserressourcen. Die Verfügbarkeit von Frischwasser in Indien wird laut Schätzungen im Jahr 2025 pro Kopf von gegenwärtigen 1608 m^3 auf 1340 m^3 sinken. Jedoch kann Indiens Problem schwindender Wasserressourcen nur sehr schwer begegnet werden. Bereits jetzt hat Indien mit mehr als 5000 großen Dämmen und 11.7 Millionen Rohrbrunnen den weltweit höchsten Frischwasserverbrauch des Jahres.

Vor dem Hintergrund dieser zahlreichen und miteinander verflochtenen Probleme bezeugen aktuelle wissenschaftliche Entwicklungen die Notwendigkeit eines fundamentalen Wandels in der Art und Weise, wie wir Wasser als Gut wahrnehmen, seinen Gebrauch handhaben und unsere Wasserinfrastrukturen designen. Der moderne Ansatz, Wasser lediglich als Ware anzusehen und die damit verbundene Infrastruktur auf maximale Ausbeutung natürlicher Wasserressourcen zu konzipieren, muss überwunden werden. Stattdessen soll ein nachhaltiger Ansatz gewählt werden, mit geringen Auswirkungen auf natürliche Wasserkreisläufe. Dieser Ansatz versucht, den gesellschaftlichen Frischwasserverbrauch zu regeln und konzentriert sich auf das Sammeln von Regenwasser und das Recyclen von Abwasser. Besonders im Kontext Indiens rät der Ansatz dazu, das traditionelle Wissen über Wassermanagement und nachhaltige, auf Umleitung und Speicherung von Regenwasser und Oberflächenabfluss basierende Wasserinfrastruktursysteme, wiederzubeleben.

Die gegenwärtige Beforschung traditioneller Wasserinfrastrukturen in Indien konzentriert sich auf deren technische und verwalterische Aspekte. Ein vergleichsweise geringer Teil der Forschung fokussiert den räumlichen Aspekt dieser Strukturen und die Art und Weise, wie diese in Siedlungsgebiete integriert wurden. Außerdem liefert die Mehrzahl dieser Studien lediglich überblicksartige Aufzählungen über die verschiedenen traditionellen Wasserinfrastruktursysteme Indiens. Das soziokulturelle Gefüge hingegen, in dem diese Strukturen florierten, sowie die Gründe für ihren Untergang und ihre Bedeutung im gegenwärtigen Kontext, wurden in den meisten Untersuchungen bislang nur am Rande thematisiert. Um diese Lücke zu schließen, nimmt die vorliegende Arbeit den Wert traditioneller Wasserinfrastrukturen (TWI) für die Erschaffung eines neuen Wasserbewusstseins aus einer soziokulturellen Perspektive in den Blick und verfolgt den Anspruch, Wasserinfrastrukturen kreativ neu zu denken. Am Beispiel von Pune, Indien, wird

zunächst untersucht, wie kulturelle Überzeugungen und Ideen traditionelle Wasserinfrastrukturen formten und beeinflussten. In einem weiteren Schritt folgt die Analyse der räumlichen und architektonischen Prinzipien traditioneller Wasserinfrastrukturen am Beispiel bestehender Zisternen, Stufentanks, unterirdischer Aquädukteund künstlich angelegter Seen in Pune. In der Arbeit wird ebenfalls auf die Gründe für den Niedergang traditioneller Wasserinfrastrukturen während der britischen Kolonialzeit und der postkolonialen Periode eingegangen.

Diese Arbeit stützt sich auf Daten aus Archivbesuchen im Februar und September 2017, sowie auf Feldforschung, Fotodokumentation und Maßzeichnungen, die zwischen Februar und März 2018 und zwischen November und Dezember 2018 gemacht wurden. Die Ergebnisse zeigen, dass einerseits die geringe Verfügbarkeit von Wasser durch intermittierende Gewässer und andererseits das Übermaß an Regenwasser zur Monsunzeit in traditionellen Gemeinschaften zur Ausprägung eines bewussten und bedachten Umgangs mit Wasser, also zu einer eigenen Wasserkultur, beitrugen. Die Werte, Überzeugungen und Ideen, die aus dieser Wasserkultur hervorgingen, haben die traditionellen Wasserinfrastrukturen Punes nachhaltig geformt. Diese Strukturen waren auf die Örtlichkeiten angepasst, durch öffentliche Teilhabe konstruiert und unterstanden der Schirmherrschaft der Regenten. Im Gegensatz zu modernen, nutzenorienterten Strukturen, waren diese traditionellen Strukturen öffentliche Orte der Begegnung und Interaktion, an denen alltägliche Rituale praktiziert wurden.

Trotz ihrer kritischen Rolle bei der nachhaltigen Wasserversorgung verloren traditionelle Wasserinfrastrukturen während der britischen Kolonial- und Postkolonialzeit an Bedeutung. Der Eingriff der britischen Besatzung in die soziokulturelle Lebenswelt der indischen Bevölkerung und der Mangel an Verantwortung für die Konstruktion und Instandhaltung bestehender Wasserinfrastrukturen zwang die Bevölkerung dazu, auf traditionelle Strukturen zu verzichten und stattdessen moderne Infrastrukturen, bestehend aus Dämmen Dämme und Kanälen, zu benutzen. Selbst nach der Indischen Unabhängigkeit führte das Bestreben indischer Nationalisten, das Land als moderne und progressive Nation darzustellen, zu einer Ausweitung zentralisierter Wasserinfrastrukturen und zur weiteren Vernachlässigung traditioneller Strukturen. Zur selben Zeit führte der schnelle demographische Wandel und die physische Expansion Punes zu einer steigenden Nachfrage nach Wasser, was die Implementierung schneller Lösungen, wie etwa den Bau von Brunnen zur Grundwassernutzung begünstigte. Trotz der geringen Nachhaltigkeit moderner Systeme wurden traditionelle Wasserinfrastrukturen durch bequeme und einfache Lösungsansätze verdrängt.

Im Licht dieser Erkenntnisse schlussfolgert die vorliegende Arbeit, dass das Wiederauftauchen traditionellen Wissens über die Verteilung und das Management von Wasser, als wertvolles Gut und nicht als Ware, für das Wiedererstarken eines bewussteren Umgangs mit Wasser als Gutmoderat denkenden Wasserbewusstseins essenziell ist. Von traditionellen

Wasserinfrastrukturen lernen bedeutet, zukünftige Herausforderungen der Wasserversorgung neu zu denken, um kreative und nachhaltige Lösungen für künftige Probleme zu finden. Abschließend werden vier Vorschäge formuliert, wie traditionelle Wasserinfrastrukturen zur Lösung von Wasserversorgungsproblemen und zu einer verbesserten Qualität der Umwelt beitragen können. Erstens kann die Reparatur traditioneller und der Neubau vergleichbarer kleinerer Wasserspeicher zur Diversifikation von Wasserressourcen beitragen. Viele kleine und dezentralisierte Wasserspeicher erhöhen die Resilienz von Wasserressourcen im Gegensatz zu einem einzigen zentralisierten System, besonders im Bezug auf Umweltkatastrophen. Zweitens können traditionelle Wasserinfrastrukturen schwammartig Regenwasser aus urbanen Gegenden speichern und somit den negativen Effekten von Überschwemmungen entgegenwirken. Drittens kann der Schutz kleiner Gewässer die Biodiversität der Natur gewährleisten. Kleinere Gewässer sind oft natürliche Habitate für besondere Flora und Fauna. Außerdem hat die Nutzung traditioneller Wasserinfrastrukturen in Städten weitere positive Effekte, wie etwa die Reduzierung der Oberflächentemperatur durch Verdunstungskälte, was unter anderem dem Wärmeinseleffekt vorbeugen kann. Zu guter Letzt können traditionelle Wasserinfrastrukturen als Plätze des öffentlichen Lebens, der Begegnung und der Ruhe dienen, an denen Wasser als kulturelles Gut erlebbar wird.

Auf diesen Schlussfolgerungen und Vorschlägen aufbauend verweist diese Arbeit auf die Tatsache, dass künftige Probleme der Wasserversorgung nicht allein durch den Versuch Natur durch Technik zu beherrschen, gelöst werden können. Es ist stattdessen notwendig zu akzeptieren, dass die meisten Probleme menschengemacht sind und folglich nur durch eine Korrektur unseres Handelns und unserer Wahrnehmung von Wasser gelöst werden können.

Keywords: Traditionelle Wasserinfrastrukturen, Kultur, Pune, Indien

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Glossary of Indian terms

adnyapatra	The official order of a ruler
airavat	An elephant with seven trunks considered to be the vehicle of Indra, the Hindu deity of rain.
apsaras	Beautiful female dancers believed to be staying in the court of Indra: the lord of the sky. Sometimes they considered as water nymphs.
Arthashashtra	Ancient Hindu treatise written by the Indian Scholar Kautilya on statecraft, economic affairs and military strategy in 2^{nd}-3^{rd} centuries A.D.
barav	Stepped groundwater tanks having one or more mid-landings.
baug	garden
bavdi	Wells built by the Islamic dynasties.
Bhimak	Name of a demon.
bigha	The ancient Indian unit of measuring the area of land. 1 bigha= 5/8 acre
Brahmin	Sanskrit word meaning the one who expands. Upper caste in Hindu religion.
chaitya	Buddhist rock-cut prayer halls.
Deccan	The geographical portion of western India bounded by Vindhya and Satpuda mountain ranges to the north, and mountain ranges called as Eastern and Western Ghats an east and west respectively.
devkoshtas	Niches in the parapet wall of groundwater structure containing an image of deities.
devrai	Sacred forest belonging to God as per the Hindu belief, especially in the Indian state of Maharashtra. People were prevented from disturbing or interfering in this forest. It acted as a bio reserve.
drona	Ancient Indian unit for measuring rainfall. 1 drona= 50.8 mm
Eknath	A Marathi philosopher and saint

Gajanak	Name of a demon.
Ganesh	Hindu Lord of wisdom having the head of an elephant.
haud	cistern
Indra	Hindu deity of rain.
karanje	fountain
Khandoba	A form of Lord Vishnu worshipped in the Indian state of Maharashtra
kund	Stepped groundwater storage tanks.
mandap	Pillared pavilion
mandir	temple
Mastani	Princess of Bundelkhand and wife of Peshwe Bajirao-I.
nahar	Underground aqueducts transporting water from a distant source to settlement by the use of gravitational force.
nala	A stream. Usually referred to one draining surface-runoff into the river
odha	stream, rivulet
Parvati	A hillock in Pune with a temple of Shiva on its top.
peth	An administrative unit of old Pune, which usually contained people having one particular occupation.
podhi (s)/ podhya (p)	Buddhist rock-cut water cistern.
Punaka	Ancient name of Pune in Prakrit language of India.
Punya	The ancient name of Pune in Sanskrit language of India meaning sacred.
Puranas	Ancient Hindu scriptures usually believed to consist of myths and legends.
qanat	Persian underground tunnels transporting water from a high altitude water source to a settlement by use of gravitational force.

rahat	A rotary drum-like mechanical device for extracting water from water storage structures.
rahat gadge	A rotary drum-like mechanical device having a chain of mud pots tied to it for extracting water from water storage structures.
Shiva	The Lord of destruction, according to Hindu religious belief.
Somebhairavnath	A form of Lord Shiva, the Hindu God of destruction.
swarajya	Self-rule
taaki (s)/ taakya (p)	Hindu rock-cut cisterns.
taluka	An administrative unit consisting of a group of villages.
tirtha	To cross over. Sacred spots in Indian landscape having special religious significance.
Triveni Sangam	The confluence of three rivers
ucchwas	Air-shaft
Varaha	Incarnation of Lord Vishnu having the head of a boar.
varshamana	Ancient Indian device for measuring rainfall
Varuna	Hindu deity of the ocean or sometimes believed to the god of rain.
Vedas	Ancient Hindu knowledge scriptures in Sanskrit. The four Vedas are Rigveda, Yajurveda, Samveda, and Atharvaveda. The Rigveda is supposed to be the oldest of them. Some of the verses were composed around 4000 B.C.
vihara	Buddhist rock-cut living cells.
Vishnu	Hindu Lord considered being the guardian of the universe.
wada	Old residential structures in Pune having internal courtyards.

Acronyms of References

ASI	Archaeological Survey of India
BES	Bureau of Economics and Statistics
CGDB	Central Groundwater Development Board
DCO	Directorate of Census Operations
DSA	District Superintendent of Agriculture
EIC	East India Company
FAO	Food and Agriculture Organization of the United Nations
GBP	Gazetteer of Bombay Presidency
GBS	Gazetteer of Bombay State
GOI	Government of India
GOM	Government of Maharashtra
GSDA	Groundwater Surveys and Development Agency
ICOLD	International Commission on Large Dams
ICSU	International Council for Science
IIC	Indian Irrigation Commission
IMD	Indian Meteorological Department
MUD	Ministry of Urban Development
NRLD	National Register of Large Dams
PMC	Pune Municipal Corporation
PMRDA	Pune Metropolitan Region Development Authority
PMRPB	Pune Metropolitan Regional Planning Board

1. Introduction

This chapter discusses the different water-related problems that have emerged due to extreme human intervention in natural ecological cycles and the technology-driven approach of water management. By undertaking the case of Pune District in India, it attempts to look beyond the technology-driven approach and aims to explore the role of culture and traditional water structures in the management and design of current water infrastructure. Followed by this, it discusses the research methodology and different methods used for collecting data. It ends by presenting a brief outline of the succeeding chapters.

1.1. Background: Water-related problems and technology-driven approach

The water on earth is finite. Although, the earth is a blue planet with water occupying nearly two-thirds of its surface area, less than 2% of it is freshwater (Hoekstra, 1998, p.33), fit for the consumption of plants, animals and humans. In addition, the same 2% of water runs the various ecological cycles in nature. Although we know that chemically water is H_2O, we cannot combine two hydrogen atoms with one oxygen atom in the laboratory to manufacture water (Clark, 2007, p.1). Thus, we have to depend on the natural hydrological cycle for fulfilling our varied water requirements – be it biological, domestic, irrigation, or industrial. Due to this limited availability of water and the diverse needs that depend on it, water becomes a critical natural resource.

The distribution of this finite fresh water available on earth is uneven across space and time. Nine countries of the world share 60% of the world's fresh water, while 186 countries share the remaining 40% water (FAO, 2016).[1] At the country level, the availability of total renewable water resources varies. Canada, Iceland, Gabon, and Suriname have 10000m^3 water per inhabitant, while Kuwait has only 10m^3 water per inhabitant (ibid). Also, the water received mainly in the form of precipitation varies temporarily in different countries. For instance, in the UK, the average annual rainfall of 885mm is distributed over the entire year. In each month, there are at least 5 to 10 rainy days (Tiseo, 2019, p.1). On the contrary, although India has an average annual rainfall of 1100mm, 75% to 90% of it is received from June to September and in about 100 hours (IMD, 2016, p.1). Thus, the uneven spatial and temporal distribution of rainfall puts additional pressure on countries that receive little rain and only during specific months of the year.

Furthermore, population explosion, rapid urbanisation and extreme human intervention in the natural ecological cycles resulting in climate change exert additional pressure on the water infrastructure of many countries across the world (McGrane, 2016, p.2295; Liyange and Yamada, 2017, p.1). The problems of overburdened water infrastructure, the inadequacy of

[1] The nine countries are Brazil, Russia, Canada, Indonesia, China Mainland, Colombia, U.S.A, Peru, and India

wastewater treatment and high environmental risks due to extreme weather events such as floods, droughts and typhoons are common in many countries.[2] Many of the Asian and African countries are highly vulnerable to floods. By 2030, nearly 54 million people worldwide would be affected by floods (Luo et al., 2015). Similarly, many cities in industrialising countries are extremely vulnerable to droughts and even depletion of freshwater resources (Arcanjo, 2018, pp.3-4).

These water-related problems such as floods and droughts are not merely natural but often resultants of direct human intervention in the natural water cycle at local, regional and national scales causing global impacts (Pahl-Wostl et al., 2013, p.708). Specifically, these problems are the problems of today's modern societies where we modify the water cycle dramatically through unprecedented construction of water infrastructure for water supply, hydropower and irrigation (Gleick, 2000, p.127). These water-related problems are often a direct outcome of our water management practices and the way we design our water infrastructure without considering the long-term consequences (Pahl-Wostl et al., 2006).

Current water infrastructure has evolved from a strong engineering tradition of controlling water-related environmental problems with technological solutions (Brooks, 2005, p.84). This technology-oriented approach of water management termed as the 'hard-path approach' by Gleick (2000), and Gleick and Wolff (2002) forms the basis for designing current water infrastructure across the globe. The hard path approach of water management considers future population projections, growing per capita water demand and increasing agricultural and economic activity while designing water infrastructure. As water demand rises, planners come up with supply-side solutions. They plan the construction of more physical infrastructure such as large dams, reservoirs, tubewells, and so on to meet the increased water demand (Gleick, 2000, p.128). Such an approach fails to understand the wider role of water in society. It fails to realise that water is not only a physical substance, a biological necessity, or a scarce resource but also a part of people's identities, cultures, worldviews, and religious perceptions (Oestigaard, 2009, p.11).

The technological approach of water management has a history dating back to the early 19th century. In the aftermaths of the industrial revolution in Europe, the release of industrial wastes into the local water bodies polluted the drinking water of many European cities. Consumption of polluted water led to the spread of water-borne epidemics amongst people such as cholera (Domenech, 2011, p.295). There was an urgent necessity to control their spread by providing safe and clean drinking water free from any pollutants. This necessity was fulfilled by damming rivers, building water treatment plants and carrying treated potable water to households by laying a grid of water-supply pipes. Paris in 1802, London in 1808 and Berlin in 1856 were some of the early cities in Europe to have such centralised water infrastructure and network of

[2] World's 15 most vulnerable countries to floods are India, Bangladesh, China, Vietnam, Afghanistan, Nigeria, Brazil, Thailand, Democratic Republic of Congo, Iraq, and Cambodia (Luo et al., 2015).

water-supply pipes (Gandy, 2004, p.366). This water infrastructure acted as a quick technological fix to the problem of water pollution. It had its inherent advantages such as streamlined operations, centralised control, and economy and reliability of scale (Galada et al., 2014, p.2). Moreover, it was useful in controlling the spread of water-borne epidemics, which brought down the death rate in European countries (Geels, 2005, p.371). Simultaneously, construction of dams and expansion of irrigation facilities helped to increase the food production, thereby reducing the rate of undernourishment in Europe (ibid).

Use of modern technology and centralised water infrastructure for solving water-related problems worked well when the issues were simple such as water pollution (Pahl-Wostl et al., 2006, section 1). However, the belief that modern technology alone can solve water-related problems by controlling natural sources of water was problematic. The insensitive use of modern technology created problems of large-scale human displacement, fragmentation of rivers, sedimentation, waterlogging, alteration of riparian zones and many more (see Goudie, 1981; Baghel, 2014, pp.3-7). Instead of tackling these problems, current water management practices attempt to mask these socio-ecological realities. They bury the water infrastructure underneath the ground to break the ties between water and its production process (Kaika and Swyngedouw, 2000, p.121). Distantly located dams, water reservoirs, treatment plants, and hidden water pipes manage to severe us from the harsh realities of the production process and the resulting problems (ibid).

Moreover, the attempt to objectivise infrastructure creates a differentiation between spatial design and water infrastructure (Stadler and Daro, 2017, p.28).[3] The design of water infrastructure with its sophisticated technologies is imagined to serve specific functions. It is separated from the realm of spatial design and considered to be the responsibility of a specialist of that particular field. Thus, water infrastructure that had traditionally been the precondition of settlement design has become an add-on entity to be superimposed as an invisible layer upon the existing fabric of a settlement (ibid). Invisible water infrastructure lacks the potential to shape urban form and meeting human, ecological and aesthetic objectives (Perysinaki, 2010, p.1). Due to its hidden character, we fail to see, hear, touch, and experience water flowing through parts of our settlements.

Against the background of all these challenges such as climate change, rapidly depleting water resources and rapid urbanisation, a paradigm shift in water management can be seen (Pahl-Wostl et al., 2008, p.484; Vairavamoorthy et al., 2015, p.51). This paradigm shift suggests shifting from the technology-driven approach towards a sustainable path of water management that does not seek to find solutions to water-related problems by searching for new sources of water. Instead, it attempts to have effective water management. It suggests having a carefully

[3] I borrow this idea from Stadler and Daro (2017) who discuss about the differentiation between architecture and infrastructure design in their essay, ‘Eight points on infrastructure and architecture’.

planned centralised water infrastructure that is effectively complemented by community-managed low-cost decentralised water systems (Gleick, 2003, p.1526).

1.1.1. Paradigm shift in water management

For having decentralised water management, planners point out at innovative ways of designing water infrastructure. For instance, Wong and Brown (2008) imagine the cities themselves as water catchment areas. They suggest the use of various alternative sources of water supply such as groundwater, urban stormwater, rainwater (roof runoff), recycled wastewater, and desalinated water. According to them, having access to a wide variety of water sources would reduce the dependency on the centralised water infrastructure and ensure resilience to future uncertainties of water (Wong and Brown, 2008, pp.4-8). Furthermore, water would once again be a part of the urban landscape. It would improve the urban environment and reconnect people to natural water sources. Domenech (2011) puts forth a similar suggestion of accessing a variety of decentralised water systems to enhance water security and minimise environmental degradation. She recommends rooftop rainwater harvesting and greywater reuse as ways of diversifying water sources.

Perysinaki (2010) and, Rudolph-Cleff and Shankar (forthcoming) take a different stand on water infrastructure. They identify that the problem with current water infrastructure is not about lack of diversity but lack of visibility. Their concern is about integrating water infrastructure with landscape and architectural design. Therefore, they suggest ways of making water visible to people, which would improve their connection with water. A somewhat similar suggestion is given by Dicks (2014) who argues that letting water appear in the city would lead to the sustainable management of water. He suggests four ways of making water appear: i) Daylighting rivers and streams[4], ii) Harvesting local rain and groundwater, iii) Treating wastewater on-site through living machines[5], and iv) Attuning demand to local water flows[6]. In short, the various decentralised water management solutions emphasise the need for diversifying water sources and overcoming the disintegration between water infrastructure design and settlement design.

Although the research solutions discussed above are innovative and attempt towards making water management sustainable in future, they have certain limitations.

Firstly, these solutions emerge from countries of Global North, where there exists a universal and uniform centralised water infrastructure. Therefore, the concern of planners is complementing this uniformity with diversity by introducing new diverse, decentralised

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[4] Daylighting is the process of unconcealing rivers and streams that have been lost or filled up to build structures over them.
[5] Living machines include bacteria, algae, fish, and other microscopic animals that utilize sunlight to treat sewage.
[6] Attuning to local flows means to adjust demand according to natural flows and replenishing capacity of water bodies

systems. However, in countries of Global South, water infrastructure is heterogeneous where centralised water infrastructure already co-exists along with infrastructure initiated by local entrepreneurs, grassroots organisations, NGOs and individuals (Lawhon et al., 2017, pg.4; Wamuchiru, 2017, p.14). As a result, the concern in countries such as India is not to introduce diversity but maintain the existing diversity.

Secondly, although the decentralised solutions aim to move away from the technology-driven approach, techniques such as wastewater and greywater recycling are technology-dependent and often expensive. Application of high-cost techniques becomes difficult in industrialising countries such as India, which lacks the necessary financial resources for their use. One has to opt for cheaper solutions.

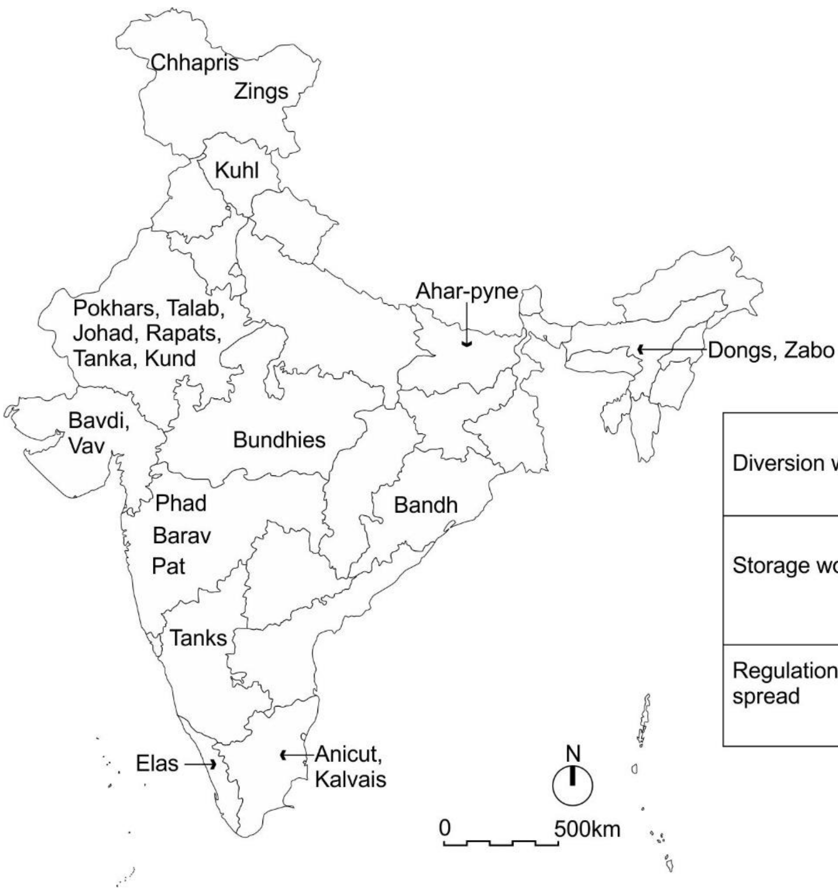
Thirdly, the design parameters for rainwater harvesting and stormwater runoff have been developed to suit the temperate climatic conditions of Europe which experience constant level of rainfall throughout the year (Hoyer et al., 2011, p.17). On the contrary, monsoon-dependent countries such as India receive more than 75% of the total rainfall within the four months of monsoon and in less than 100 hours as mentioned before. Thus, the design parameters for rainwater harvesting and surface runoff developed with European experience need to be suitably adapted before they are implemented in India. Moreover, India itself has a long tradition of building rainwater harvesting structures, which is better suitable for its monsoon conditions.

Lastly, the alternative solutions of water management do not emphasise the importance of imbibing conscious water behaviour amongst people to prevent wasteful utilisation of water. According to LaFreniere (1989), the unsustainable ways of using natural resources such as water, developed in the era of abundance and diminishing cultural values. Therefore, to solve water-related problems, it is essential to treat 'cultural illness' rather than seeking solutions to water-related problems, which are its symptoms (LaFreniere, 1989, p.144). In short, a paradigm shift in water management has to identify water-related issues in their specific context and avoid generalised solutions.

1.2. India: Negligence of traditional water infrastructure

India has a rich tradition of constructing diverse Traditional Water Infrastructure (TWI) in the form of wells, stepped tanks, water channels, aqueducts, and cisterns for storing rain, surface runoff and groundwater. These diverse forms of TWI once dotted the landscape of most ancient Indian settlements and were known by different names in different parts of India (refer Figure 1.1.). Their construction developed through a deep understanding of the geography, topography, hydrology, climate, and ecology of the place (Stokman, 2008, p.52). TWI had a strong cultural and religious dimension. The varied forms of TWI did not merely serve the utilitarian function but also functioned as places for performing daily routine, religious rituals and social gathering. Moreover, it was built through the collaboration of kings, noblemen, and common people. Although conflicts over water sharing did arise occasionally, they were solved within the community (Jacob, 2013, pp.3-4).

This TWI developed through several generations of close observation of nature suited the Indian conditions. It was decentralised and sustainable. At first, TWI even impressed the British who invaded India in the 17th century (Agarwal et al., 2001, p.292). However, it was unsuitable for fulfilling their motive of gaining productive control over India's water resources and earning revenue by imposing taxes. Therefore, the British chose to build dams and canals as they allowed for centralised management and control (Sengupta, 2007, p.122). After gaining independence in 1947, the Indian Government had the opportunity to revive back the TWI and at the same time construct future water infrastructure in a sustainable manner. However, Indian nationalists and foreign-trained engineers were impressed by the water infrastructure in the United States, Soviet Russia, and Japan (Guha, 2007, p.207). They continued the British trajectory of constructing large-scale water infrastructure with the firm belief that it displayed India's path towards progress and modernity. However, the cultural, political, biophysical complexities, and the erratic nature of monsoon in India consistently mitigated against the comprehensive modernisation of India (Gandy, 2008, p.126). The water infrastructure derived from the European experience was unsuitable to the Indian context.



Diversion works	Anicut, Phad, Pynes, Pat, Rapats, Zings
Storage works	Ahar, Bandh, Johad, Bundhies, Pokhar, Talab, Johad, Chhapris, Barav, Kund, Tanka, Bavdi, Vav, Tanks
Regulation of spread	Elas, Dongs

Figure 1.1: Different forms of Traditional Water Infrastructure found in India.
Source: Adapted from Sengupta, 1993.

The endeavour of Indian political thought to portray India as a modern nation coupled with a supply-driven approach of water management has led to the construction of massive modern water infrastructure whose success remains questionable. India, with 5100 large dams,[7] ranks third in the list of countries having the most number of dams after China and USA (ICOLD, 2018). In terms of groundwater usage, India ranked first in 2010 with highest annual groundwater extraction of 230 cu.km. (The World Bank, 2010, p.1). In 2013-2014, there were 11.7 million tubewells in India (Minor Irrigation Census, 2017, p.27). In spite of such infrastructure, 30% of India's urban population and 65% of the rural population lacked household access to water in 2011 (Planning Commission, 2013, p.301). In the case of agriculture, out of the total cultivated area, only 45% received irrigation (Agricultural Census, 2015, p.39, Table 4A). Thus, the desired objectives of centralised water infrastructure to provide adequate water supply for domestic and irrigation purpose have been unachieved. At the same time, the supply-driven approach of water management has drastically reduced the per capita water availability in India from 1816 cu.m per person in 2001 to 1608 in 2010 (Central Water Commission, 2015, p.31). It is expected to drop further to 1340 cu.m by 2025. Also, large-scale construction of centralised water infrastructure has caused alteration in sedimentation patterns of rivers, waterlogging, salination, land submergence and displacement of about 25 million people between 1950 and 2000 (Baghel, 2014, p.5).

Thus, with changed urban realities, increased pressure on water resources and the socio-ecological damages already caused by current water infrastructure, the technology-driven approach of designing water infrastructure is being criticised in India. Many environmentalists, water conservationists, and planners find it necessary to resurface the cultural values imbued in India's traditional water management. They argue that water management strategies of the future must consider the significance of India's rich water-culture and traditional water infrastructure in solving water-related problems. The next section takes a review of their key arguments.

1.3. Literature Review: Revival of traditional water infrastructure

Some of the earlier research on TWI focused on irrigation techniques. Sengupta (1993) and Agarwal and Narain (1997) brought the neglected traditional irrigation systems to light. They did credible work in systematically classifying these irrigation techniques into various categories based on the principles of water harvesting followed by the people. Through their work, they have succeeded in capturing the geographical diversity of India and have revealed the rationale behind the evolution of specific irrigation practices at specific places. Their work helps to understand the importance of location specificity in water harvesting techniques.

[7] The International Commission on Large dams (ICOLD) specifies a dam having a height of more than 15m from its deepest foundation to its crest as a large dam. Similarly, a dam having its height between 10m to 15m is also considered a large dam provided i) the length of its crest is more than 500m, ii) has a reservoir capacity of more than one million cubic metres, iii) maximum flood discharge is more than 2000 cubic metres per second, and v) it has a special difficult foundation.

While the research of Sengupta, Agarwal and Narain focussed on irrigation systems, Mishra (1993, 1995) carried out extensive research on the surface-runoff and rainwater storage structures of Rajasthan. The focus of his research was not on irrigation but instead on the water conscious culture and wisdom of building sustainable water structures that enabled the people to flourish in desert conditions of Rajasthan with rainfall as low as 200mm. While Mishra's research focussed mostly on the structures of Rajasthan, Mate (1998) discussed how ancient Indians used their scientific knowledge to build diverse water infrastructure all over India. The focus of his discussion has been on the history of water science and technology in India.

Agarwal et al. (2001) have focussed on the community managerial aspects of TWI as part of commons. Through examples of various community-managed systems, they discuss the aspects of water sharing, water equity and bottom-up governance.

Although the research works discussed so far are valuable, a common point missing in them was a detailed discussion on the art and architecture of traditional water structures. This gap was filled up by the works of Hegewald (2002) and Jain-Neubauer (2016). Both of them focus on the artistic and architectural aspects and details of traditional water structures. They also explained how people's perception of water gains a physical form through the construction of water structures. Through their work, they manage to look beyond the utilitarian aspect of water structures and understand its cultural, religious and social significance.

All the research works are valuable and help to gain an in-depth understanding of TWI. However, in examining the role of TWI in solving water-related problems, this research attempts to address the following gaps:

1.3.1. Gaps

Firstly, from spatial design and landscape perspective, water infrastructure is not a mere utilitarian service. It plays an active role in shaping the spatial form of landscapes and has religious and cultural significance. However, the focus of researchers has been more on the technical and managerial aspects of TWI. Their discussion on TWI has been inclined towards techniques of water storage and transportation, systems of governance and management. Comparatively, there has been little discussion on the spatial aspect of TWI such as its placement within the settlement, orientation, its architecture, and role of TWI in place making. All these factors are critical in case of TWI, which is location specific and was often the precondition for the design of settlements.

Secondly, very few studies discuss the operation of TWI in changed socio-cultural realities. Most of the studies discuss the need to conserve TWI due to its heritage value, which is a valid argument. However, very few talk about the adaptive reuse of TWI to solve the current ecological problems, especially in the urban areas. For instance, Mundoli et al. (2016) have discussed how traditional lakes and ponds in Bangalore as urban commons could play an essential role in improving its larger environment. They could support ecological functions like flood control, maintaining microclimate and recharging the water table. Similarly, Inokai (2007) suggest that the sacred tanks and ponds within the temples of Melkote town in Karnataka could act as places for social gatherings and sites for harvesting precious rainwater in the current context. Apart from these and a few other studies, little is discussed about the adaptive reuse of TWI.

Lastly, in attempting to portray the diversity of TWI in India, very few studies examine the TWI of a specific region in detail considering its history, location specificity and architectural characteristics. There also exist some regional imbalances in literature. For instance, the water harvesting structures of Rajasthan and Gujarat, the tanks of South India find frequent mention in the works of many researchers discussed so far. However, the water harvesting structures such as rock-cut water cisterns, stepped water tanks, artificial lakes and underground aqueducts in the Deccan region of Maharashtra State have received less attention in spite of their architectural significance.

This research attempts to addresses these gaps in current research on TWI. It does not merely engage in the discussion about the need for conserving TWI. Instead, it attempts to look deeper into the aspects of history, context, settlement design, cultural setup and social fabric within which TWI operated. Analysing these aspects would lead to a better understanding of TWI as a possible source for learning, innovating and reimagining the current technology-driven water infrastructure differently. For fulfilling these criteria, the research takes up the case of Pune District within the State of Maharashtra in India.

1.4. Case of Pune

Pune district with 9.4 million people ranks second in the state of Maharashtra and fourth in India in terms of population (DCO, 2014, pp.12-13). The district consists of 1866 villages, 13 towns, and two cities of Pune and Pimpri-Chinchwad. Pune city with a population of 3.1 million people is the ninth-largest metropolitan city in India. The average annual rainfall of Pune is about 715mm (CGDB, 2013, p.5). It is moderate in comparison with the average yearly rainfall of 1100 mm in India. Geographically, Pune is part of the Deccan Plateau Region. A vast area of Pune is made up of hard basalt rock. Its water-bearing capacity depends upon the extent of rupturing and fracturing within the rock bed. Depending on the extent of rupturing, groundwater is present at a depth of 20m to 40m below ground or even deeper (CGDB, 2013, pp.7-8). Massive portions of basaltic strata are devoid of water. Therefore, groundwater utilisation needs to be undertaken with caution as over-extraction of groundwater beyond its replenishment capacity can lower the groundwater table significantly.

These climatic, geological and hydrological conditions of Pune have strongly influenced the diverse forms of TWI in Pune. These forms include water storage structures such as *podhis and taakya* (rock-cut water cisterns), *kunds and baravs* (stepped water tanks), *talavs* (lakes); and water conveyance structures such as *nahars* (underground aqueducts). Many of these structures are more than eight hundred years old and continue to be utilized by people even today. Apart from these water structures that once dotted the landscape of Pune, the old settlement of Pune itself has a strong connection with the two rivers Mula and Mutha flowing through it. 'Punaka' the name of the ancient settlement of Pune means a sacred place developed near the confluence of the two rivers: Mula and Mutha (Gadgil, 1945, p.3).

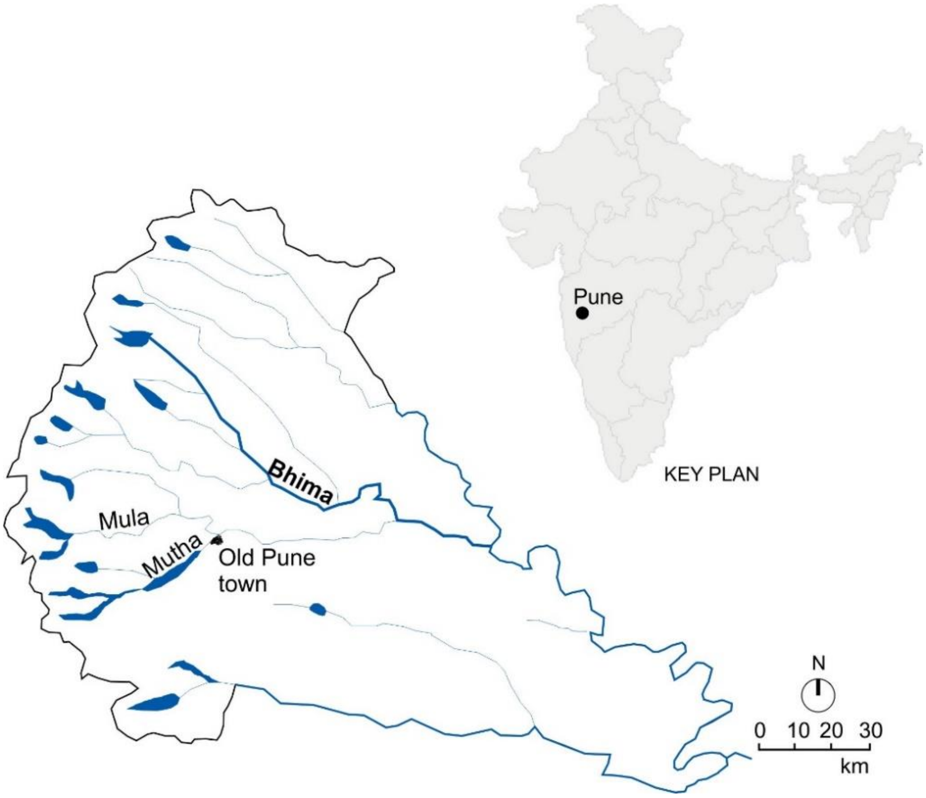


Figure 1.2: Map showing the location and expanse of Pune district
Source: Adapted from PMRDA, 2016.

A water-conscious culture in the society complemented the location-specific design of traditional water infrastructure. In villages, traditional agriculture practised the cultivation of crops such as millets, sorghum and groundnut which require less water and water-intensive crops such as sugarcane were avoided or cultivated in rotation (IIC, 1903, p.62). Whenever a particular village faced water scarcity, village heads and rulers financed the construction of rainwater storage structures which were built through community participation. Even in the ancient town of Pune, water cisterns were considered a part of urban commons. They were essential landmarks in the city where people gathered daily to fetch water (Gokhale, 2018, p.58)

However, the TWI of Pune declined during the British Colonial (1818-1947) and post-colonial (after 1947) periods (IIC, 1903, p.372-373; GBS-XX, 1954, p.230; Agricultural Census Division, 2017). The motive of the British behind the construction of modern water infrastructure was to expand irrigation and earn revenue by levying taxes on irrigated land and water.

Additionally, they laid the piped water supply system for supplying water mainly to the British Cantonment, which housed many British officers. After gaining independence, the construction of both rural and urban water infrastructure became intensive. The Indian nationals believed that constructing large-scale water infrastructure represented India's path towards progress and modernity. Also, the rapidly changing spatial and demographic conditions compelled the Government to opt for the piped water network. Therefore, after 1947, Pune experienced rapid expansion of modern water infrastructure.

Currently, the water infrastructure of Pune consists of 27 large dams (NRLD, 2017)[8], 1.4 million wells and about 39000 tubewells (Minor Irrigation Census, 2017). Pune city, in particular, receives 1120 MLD of daily water supply from the four dam reservoirs of Khadakwasla, Panshet, Varasgaon, and Temghar. Nine water treatment plants in the city and several pumping stations supply water to different parts of the city through 210 km length of main supply pipes and 2600 km length of distribution pipes (PMC, 2014, p.5). However, laying such immense water infrastructure without considering the physical context of Pune has not only decreased its efficiency but also given rise to new water-related problems both in rural and urban areas.

Figure 1.3: Piped water network in the outskirts of Pune city.
Source: Author. 24-02-2018.

In Pune city, simply superimposing the piped water network without considering the physical terrain has caused uneven water distribution. Certain low-lying areas within the city receive water supply of 358 lpcd while certain high altitude areas within the city receive water supply

[8] The number of large dams has been calculated by counting the total number of large dams built in Pune District from 1885-2015 as mentioned in the National Register of Large Dams (2017).

of 139 lpcd (PMC, 2018). Lack of proper maintenance of water supply pipes causes leakages, which leads to water losses to the extent of 30% to 35% (PMC, 2014, p.3ES). Domestic water supply and irrigation in the villages are dependent heavily on groundwater usage. Extensive use of tubewells has led to the depletion of groundwater table in the villages and peripheral areas of Pune where groundwater development has almost reached the level of 73%. In some areas of the district, it has reached beyond 90% (CGDB, 2013, p.14). The replacement of traditional agricultural practices of cultivating water-prudent crops by modern agricultural practices of growing water-intensive crops such as sugarcane has further intensified the use of groundwater (GSDA, 2015, p.23).

Thus, the water-related problems in Pune are complex that cannot be resolved by a supply-driven approach of water management. In fact, considering the number of large dams and the level of groundwater development in Pune, it is clear that the reason for these problems is not water inadequacy, but lack of water management and equitable distribution. As rightly pointed out by Mosse (2008) these water-related problems are part of emerging 'water crisis' that cannot be addressed within the confines of technology and engineering sciences. They need to be addressed within their regional context by undertaking a cultural and historical perspective (Mosse, 2008, p.940). In line with Mosse's argument, this research adopts a cultural framework for understanding and addressing the water-related problems in Pune as seen in the next section.

1.5. Research structure

1.5.1. Conceptual framework: The Cultural Landscape

Defining culture is difficult. It can have varied meanings and interpretations. The definition of culture as given by the UNESCO states,

[Culture is] the whole complex of distinctive spiritual, material, intellectual, and emotional features that characterize a society or a social group. It includes not only the arts and letters, but also modes of life, the fundamental rights of the human being, value systems, traditions, and beliefs. (UNESCO, 1995, p.8).

This definition states the constituents of culture, the aspects that make up a culture. However, the dimension that is particularly significant to this research in the 'nature-culture interaction' or the 'human-nature interaction'. This concept engages in the discussion of how nature is defined, perceived and experienced by humans. Castree (2001) and Soini and Dessein (2016) explain this human-nature interaction as a process of knowing, engaging and remaking. In the first step, humans attempt to make sense of things around them that leads to their intellectual and spiritual development. They develop a perspective on nature and accumulate knowledge and experience. It the second step there is broader interaction between humans and nature and the boundaries between the two are blurred. In the third step, there is a re-shaping of nature.

(Castree, 2001, pp.10-14; Soini and Dessein, 2016, pp.6-7). This reshaping of nature gives rise to the concept of 'cultural landscape' Depending on the human perceptions, their intellectual and spiritual development, and their level of interaction with nature, this reshaping of nature varies in different contexts giving rise to diverse cultural landscapes (ibid).

The concept of the cultural landscape, particularly interests architects, urban designers and landscape designers as it discusses the way humans interact, shape and give a material form to the landscape around them. The concept also helps to overcome the idea of the existence of a pure natural landscape. It recognises that no landscape is entirely free from the modification of human agency; only the degree of alteration may vary in different cultural contexts. Sauer (1925) popularised the concept of cultural landscape. He states,

The cultural landscape is fashioned out of a natural landscape by a cultural group. Culture is the agent, the natural area is the medium, the cultural landscape the result. (Sauer, 1925, p.309)

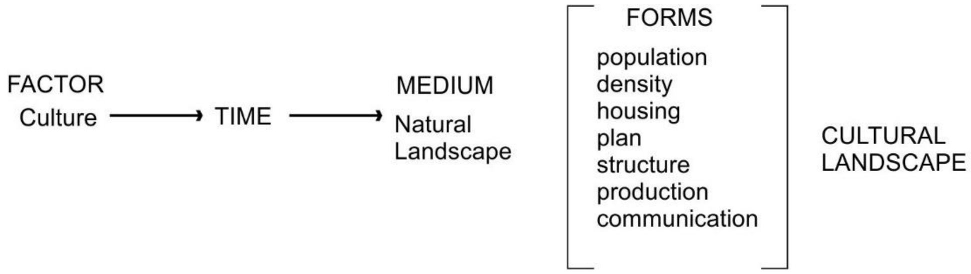


Figure 1.4: Diagram depicting the Cultural Landscape Concept of Sauer
Source: After Sauer, 1925, p.310.

However, many researchers criticise this definition given by Sauer. For instance, Shankar (2014) considers the definition of cultural landscape provided by Sauer to be valid only in theory. He states that with human intervention and perception, landscape is primarily a cultural expression and not an isolated natural system. The human perception influences landscape and therefore, it becomes a strong cultural construct of societies (Shankar, 2014, pp.4-5). Furthermore, he states that since cultural landscape is a construct of human perception, cultural landscape is bound to change with changed human perception. For instance, the idea of divinity is closely associated with nature in almost all pre-industrial societies. Many (not all) pre-industrial cultures attempted to maintain the balance of life through constant engagement with nature (Shankar, 2014, p.24). However, beginning with the Romans, humans beings considered themselves as separate from nature. Nature was understood as particulate, reductive, inert, quantitative, and mechanical that can be engineered to human specifications, irrespective of the natural consequences (Callicott and Ames, 1989, pp.5-6). The industrial revolution and modern technology represent this mechanistic image of nature due to which most of the current environmental problems arise. Therefore, to solve these environmental problems, we need to bring about a fundamental change in our mechanistic perception of nature and instead adopt a different worldview that seeks to work with nature instead of attempting to conquer nature.

Similarly, Singh (2013) argues that Sauer's definition is grounded in a clear distinction between nature and culture. He considers making such a distinction is problematic, as in reality; probably no landscape exists that is entirely natural. Even what one may perceive as natural has itself changed through geophysical, climatic, hydrological and other processes of change. From this perspective, all landscapes become natural as well as cultural. As a result, Singh gives an alternate view on the cultural landscape by using the concept of nature as presented in traditional Indian thought. Herein, nature symbolises the female energy of creation, while humans symbolise the male energy of existence. In reality both these energies co-exist and share a symbiotic relationship with each other (Singh, 2013, pp.39,46). With this idea, he defines the cultural landscape in the Indian Context.

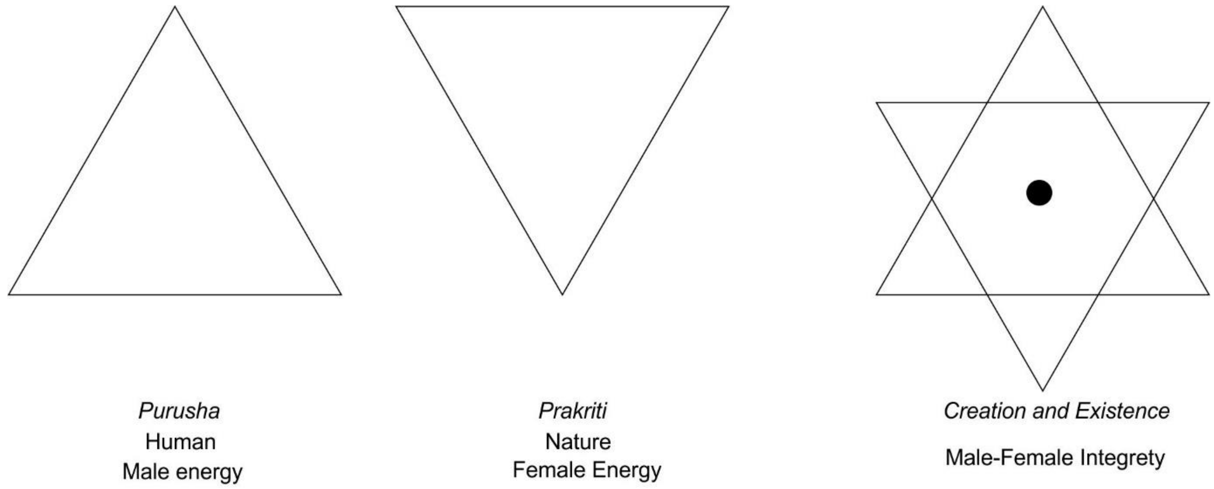


Figure 1.5: Representation of the human-nature relationship in traditional Indian thought.
Source: Singh, 2013, p.47.

1.5.2. The Indian Cultural Landscape

Singh (2013) defines Indian Cultural Landscape (ICL) as,

[A] repository of the collective perceptions of geography, where memory, information and imagination converge to shape the landscape through imaginations, realisation, memorization and continuity and finally revelation. (Singh, 2013, p.40).

The ICL has been described and exemplified in myths, legends, lyrics, oral traditions, and religious texts, as also marked on the ground through construction of shrines, temples, mortuary structures, pavilions and tombs, and various forms of built-up landscapes. [..] These [were] given a physical form by ascribing values, meaning and aesthetics and association to different forms of Nature. (Singh, 2013, p. 43).

This definition given by Singh is comprehensive as it describes both the characteristic of a cultural landscape as well as the process of its formation. Furthermore, it considers both the tangible and intangible aspects of the landscape. Therefore, this concept of cultural landscape particularly suits this research for understanding the way water infrastructure emerges through the collective perception of people coming from a particular cultural background. According to this definition, TWI is a form of built-up landscape, which is the physical manifestation of people's perception of water. This lens of cultural landscape enables us to see TWI as an inherent part of spatial design and recognise its role in shaping the visual form of settlements. Strang (2009) also takes such a perspective on water structures where she considers human-water engagement manifesting in the form of waterscapes. These waterscapes are nothing but material forms of human imagination that contain, divert, store, disperse, move, and celebrate the essence of water.

The cultural landscape perspective also enables us to understand that there is a considerable human agency involved in the construction of water infrastructure. Depending on the degree of human intervention in nature, the resultant water infrastructure may have a high or low impact on the environment. For instance, infrastructure in the form of large dams, reservoirs and long canals may have a high impact while infrastructure consisting of small water tanks, cisterns and water channels may have a low impact. Thus, understanding and correcting the set of intentions and values with which water infrastructure is designed can be a critical step towards achieving sustainability.

1.5.3. Defining Traditional Water Infrastructure (TWI)

The International Council for Science (ICSU) defines traditional knowledge as,

Traditional knowledge is a cumulative body of knowledge, know-how, practices and representations maintained and developed by people with extended histories of interaction with natural environment. These sophisticated sets of understandings, interpretations and meanings are part and parcel of a cultural complex that encompasses the language, naming and classification systems, resource use practices, ritual, spiritual and worldview. (ICSU, 2002, p.9)

Traditional knowledge is a part of culture. It has a restricted geographical scale of observation, relies on qualitative information, and builds through a long time series of observations (Berkes et al., 1995, p.283).

Based on this definition of traditional knowledge and its characteristics, this research considers the water infrastructure emerging from this traditional knowledge base as Traditional Water Infrastructure (TWI). It is place-specific and has limited transferability. It is best suited to the context, i.e. the physical, climatic and socio-cultural conditions in which it exists. In such a case, replicating the TWI of one place at another place can be problematic.

Similarly, TWI is mostly decentralised and under common public ownership. It consists of systems and structures that disallow centralised command and control. For instance, the traditional water tanks are managed within a community, belong to the community as a whole, which collectively constructs and maintains them, and shares their water. They are highly decentralised, and their bureaucratic management is not efficient (Sengupta, 1993, p.10; Jacob, 2013, p.4).

When we observe the characteristics of TWI, we can recognise the noticeable differences between TWI and modern water infrastructure. Modern water infrastructure emerges from systematic observations and universal theories of modern science. Therefore, modern infrastructure becomes universal. Modern infrastructure is suitable for bureaucratic control and centralised management, as seen in the case of canals (Sengupta, 1993, p.10).

After observing the primary differences between TWI and modern water infrastructure, we can note that in the case of India, the way infrastructure was designed underwent a significant change from the beginning of the British-Colonial Period. The dams, reservoirs and canals built by the British dominated the existing landscape and were under the bureaucratic control and central management of the British Government. Therefore, historians such as Mate (2006) and environmentalists such as Sengupta (1993, 2007), Agarwal and Narain (1997, 2001) and Shiva (2002) refer to the pre-colonial water infrastructure as traditional and the colonial and post-colonial infrastructure as modern. In case of Pune, the British-Colonial Period begins after the East India Company (EIC) defeated the last Indian Ruler Peshwe Bajirao-II (1796-1817) at the battle of Khadki in 1817.[9] As a result, this research considers the infrastructure designed before 1817, prior to the British Colonial Rule, as traditional.

Herein, it is necessary to clarify that the temporal distinction is for convenience purpose, to present the various form of TWI chronologically. The primary criterion for considering water infrastructure traditional is not temporal, but the underlying set of values, intentions and worldview with which it is built. At the same time, it is necessary to clarify that this research *does not attempt to glorify TWI* in any manner. It recognises that any form of water infrastructure always has some impact on nature and alters the natural processes in some or the other way. However, in comparison to the transformations of the fluvial regimes in the current age of Anthropocene, the alterations carried by TWI were low key and less severe.[10]

With this conceptual framework, the present research attempts to understand the human-water interaction, changing perception of water in the society in a chronological sequence within six broad historical periods:

[9] The East India Company (EIC) was a private-state company who entered India in the 16th century for carrying out trade. However, it soon started capturing the old kingdoms of Indian rulers and became a political body. In 1817, a battle took place between the EIC and Bajirao II at Khadki, near Pune. EIC emerged victorious in the battle at Pune came under its rule (GBP-XVIII, Part II, p.300).

[10] Baghel (2014) has discussed the impacts of river control, where he clearly explains that current water infrastructure projects create complex landscapes that can only be termed as technological hydroscapes.

i) The Deccan Chalcolithic Period (1700 B.C. to 800 B.C.) – river diversion system
ii) The Satvahana Period (200 B.C. to 200 A.D.) – podhis
iii) The Period of Yadavas and other Hindu Rulers (900-1400 A.D.) – taakya and barav
iv) The Deccan Sultanate Period (1300-1650 A.D.) – nahars
v) Maratha and Peshwe Period (1650-1817 A.D.) – nahars, talavs and kunds
vi) The British Colonial (1818-1947 A.D.) and the Post-Colonial Period (1947 onwards) – decline of TWI and construction of modern water infrastructure.

These six periods are indicated on the historic timeline as seen in Figure 1.6.

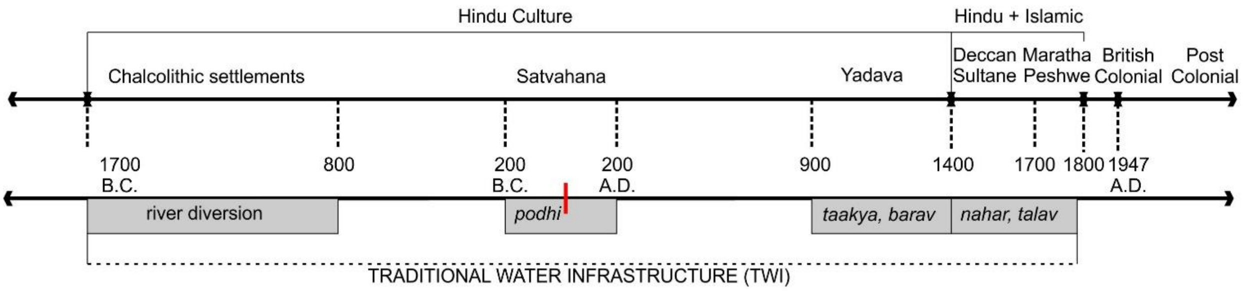


Figure 1.6: Historical timeline showing the TWI in different periods.
Source: Author. Based on information in Mate, 1998, pp.8-9.

1.5.4. Research aim and objectives

Within the conceptual framework explained above, the aim of this research is,

To understand the role and significance of Traditional Water Infrastructure (TWI) as emerging from the cultural complex of Pune in tackling the water-related problems.

The main aim stated above is too broad to be pursued in its entirety. Therefore, it is split up into four interrelated objectives which will be pursued in different chapters within the chosen methodological framework.

Objective 1: To understand the conceptualisation of water in the Indian culture.

1. What were the ideas and perceptions of people about water?
2. How did these ideas and perceptions influence the way people constructed water infrastructure?
3. To what extent did these ideas change with time?

Objective 2: To understand the working of TWI within the physical and cultural context of Pune.

1. What were the key principles behind the designing of TWI?
2. How were these principles helpful in assigning a multi-functional character to the TWI?

Objective 3: To investigate the reasons behind the decline of TWI.

1. How did the British Colonial and Post-Colonial water management policies affect TWI?
2. What was the impact of modern water infrastructure on TWI?

Objective 4: To suggest possible ways of learning from TWI

1. How can TWI be adapted suitably to the current context of Pune to solve its water-related problems?

1.5.5. Research methodology

Based on the nature of enquiry and objectives, this research employs a qualitative research methodology. Qualitative research helps to address the questions of "what", i.e. knowing what something is and "how," i.e. the process of unfolding, understanding the context and environment (Bloomberg and Volpe, 2016, p.44). Both these questions are significant in case of this research, which attempts to examine the role of TWI within the context and cultural setup of Pune.

Another characteristic feature of qualitative research is that it requires going into the field and gaining a personal qualitative understanding of the subject matter under consideration (ibid). Since one of the objectives of this research is to understand TWI as related to the physical landscape of Pune, field research is an essential aspect of this research. Through field research, this research gathers information about the physical setting, broad pattern of orientation and site-specific architectural features of TWI.

Within the framework of a qualitative approach, a case study design suits this research. A case study design is bounded by time and place. Moreover, a case study aims to avoid overgeneralizations. According to Bloomberg and Volpe (2016, p.46), generalizability is not the goal of a case study but rather the goal is transferability of knowledge (if possible) to similar contexts. It is 'context-bound'. In the case of India, it is challenging to gain a comprehensive and in-depth understanding of TWI, which shows extreme diversity. Therefore, rather than aiming for getting a mere overview of entire TWI, this research seeks to gain a comprehensive understanding of TWI within the specific context of Pune. The results obtained from this case study cannot be generalised for TWI in India as a whole. However, the methodology followed in this research can be adapted suitably for researching TWI in similar contexts.

1.5.6. Selection of case examples

The district of Pune with a geographical area of 1.5 million hectares is very extensive for covering the entire range of TWI. Therefore, this research selects specific examples from each category of TWI. The selection of case examples is based on three considerations. The first consideration while choosing the case examples has been to cover the different types of TWI belonging to different timeframes. The second consideration has been to select examples from both urban and rural context. The third consideration has been not to choose cases from one particular location of the district, but from different locations. Based on these three considerations, the following examples have been selected:

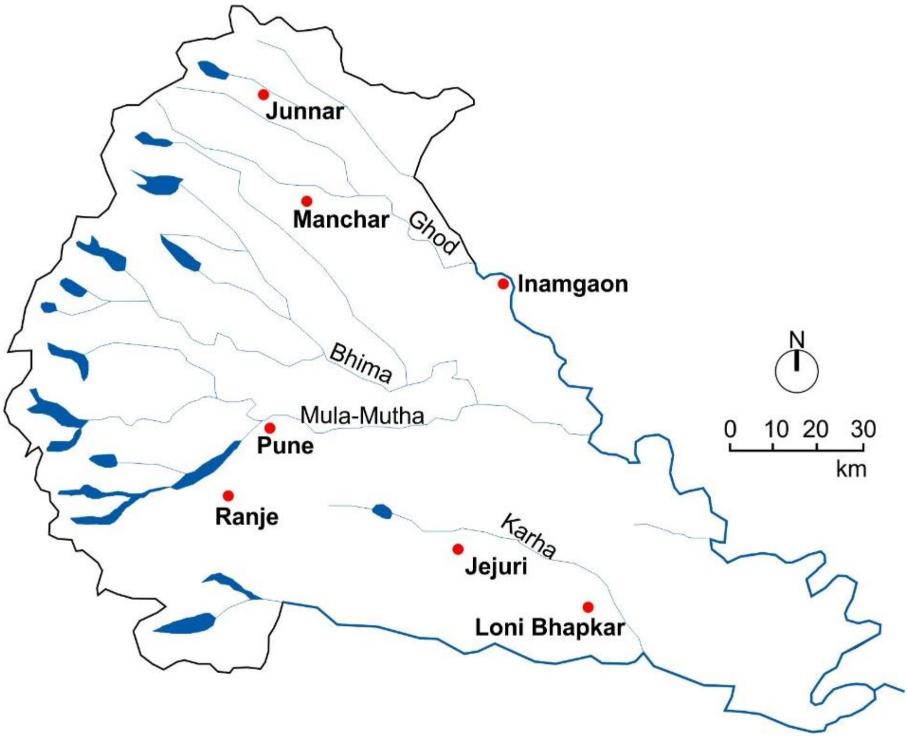


Figure 1.7: Map of Pune district showing the location of selected case examples
Source: Adapted from PMRDA (2016).

Table 1.1: Location of selected case examples

Type	Place	Taluka	Location in District
River diversion	Inamgaon	Shirur	North
Rock-cut cisterns (podhis)	Junnar	Junnar	North
Rock-cut cisterns (taakya)	Junnar	Junnar	North
Stepped tanks (barav)	Loni Bhapkar Manchar	Baramati Ambegaon	South-east North
Underground aqueducts (nahar)	Junnar Pune	Junnar Haveli	North Central
Artificial lakes (talav)	Jejuri	Purandar	South-east
Stepped tanks (kunds)	Ranje	Bhor	South

Source: Author

1.5.7. Data collection methods

This research uses multiple methods for obtaining data from varied sources. The different types of data collection methods and the sources referred for carrying out the research are as follows:

i) Document Review

Various types of archival records such as commentaries on ancient Indian scriptures, government reports, letters, maps, and photographs have been used to gain information on TWI. These records can be classified into three broad categories: - Ancient Indian records, British Records and Indian Digital Records

Ancient Indian records

Commentaries on ancient Indian scriptures

The first step of research aimed at understanding the conceptualisation of water in Hindu Culture. For this purpose, it was necessary to understand the concepts and ideas about water mentioned in some of the ancient Hindu holy scriptures such as *Vedas* and *Puranas*.[11] In addition to these holy scriptures, the research also referred to a few design principles describing the construction of water structures present in the ancient texts on art and craft making, known as *Shilpa Shastras.* Both these ancient scriptures were useful in fulfilling the first objective of the research. The information from these ancient scriptures was obtained by reading the original Sanskrit verses and understanding their correct meaning by reading the commentaries of Indian Scholars on them in either Marathi, Hindi or English.

Certain verses from the Vedas and Puranas are useful in understanding the various ideas and concepts about water in general. However, they do not go much beyond the level of ideas and concepts to discuss the craft of constructing water structures. The Shilpa Shastras do mention the construction aspects, but they are generic in the form of guidelines. Therefore, one has to use one's judgement for checking the extent to which these guidelines have been followed or whether there is a deviation from them while constructing the water structures.

Office records and government orders of Maratha and Peshwe Rulers

The Maratha and Peshwe rulers documented the expenditure incurred on various development activities. These registers are known as *daftars*. Apart from the information on expenditure, these daftars contain vital information about TWI regarding its period of construction, the labour involved in its construction and the total duration of construction. In addition to the registers, government orders issued by the rulers to the administrative staff such as the village

[11] Vedas constitute several ancient Indian hymns in Sanskrit language that were transmitted orally from one generation to the other. Puranas are ancient Indian literary accounts containing myths, legends and traditional folklore (explained later in Chapter 2).

heads or town heads shed light on the managerial aspect of TWI. The register and the government orders were written in the ancient *Modi script* of Marathi language. However, many historians and paleographers have translated these daftars into Marathi and English, which are referred to in this research for understanding the TWI built by the Maratha and Peshwe rulers.

The daftars provide useful hints for understanding the political, economic and socio-cultural aspects prevalent during the Peshwe rule. For instance, they are reliable for obtaining precise information about the person who patronised the construction of a particular water structure, the cost incurred for its construction, the labour involved and the duration of construction. However, they do not provide information about the design and construction technology of water structures.

British records

India Office Records (IOR)

India Office Records are government accounts of British involvement in India over four centuries, East India Company (1600-1858), the Board of Control (1784-1858) and the India Office (1858-1947). They are a valuable source of information on the colonial rule in India (Axelby and Nair, 2010, p.17). These records are currently part of the collections of British Library, London. They have a shelfmark starting with IOR followed by a series code such as E, F, P, L, PWD, etc. based on the original British department or office of their belonging.

These records contain information about the measures adopted by the British for maintaining TWI, as well as information on the new waterworks undertaken by them in Pune. The data from these records has been useful in understanding the condition of TWI during the British-Colonial Period as well as for knowing the waterworks undertaken by the East India Company and the British Government in Pune.

These records are excellent for understanding the administration proceedings during the British Rule in India. However, they have a strong bureaucratic and engineering outlook towards looking at waterworks. They give information about the cost, technical aspects of water infrastructure but not much about the design and socio-cultural aspect.

Maps: Poona City Survey

The most important source of information on TWI is the set of 45 maps known as ‘Poona City Survey’ published by the British in 1877. The Maps have been drawn at a scale of 50 feet to an inch (1:600) which capture in detail the settlement pattern, and location of wells and cisterns in Pune. They also show the path of the nahars built by the Peshwe rulers. Thus, these maps are the primary sources for understanding the placement of TWI; it's orientation and relation with the terrain and surroundings. Some of the drawings and sketches in this research have been prepared based on these maps.

One shortcoming of these maps is that none of them has an index clarifying the different types of lines (dotted, dashed, dot-dash) used to indicate service lines. Therefore, one can trace the paths of nahar but not the paths of drainage and stormwater lines.

Gazetteers

The British Gazetteers contain a detailed account of India's geography, history, socio-cultural and economic aspects and infrastructure. In the case of this research, the Gazetteer of Bombay Presidency, Pune District (GBP, 1885) has been referred extensively to obtain detailed information on water infrastructure during both the pre-colonial and colonial period.

However, as British Officers wrote the gazetteers, one can observe a colonial viewpoint, especially while recording the historical events. Therefore, as a historical check, the data from the gazetteers needs to be cross-verified with the data from books written by Indian authors. Also, the gazetteers were published in 1885. While recording some historical events of the Peshwe Period, there are few errors about dates. The reason for these errors is probably because the British sometimes could not access the original letters, documents of the Peshwe. Later, many of the Indian writers such as Sowani have referenced the original Peshwe letters and documents from the Peshwe Daftar, which makes their writing more authentic.

Photographs

The photographs of Pune's environs and TWI taken by the British officers during their tenure in Pune are important to understand the state and condition of the town and TWI during the British-Colonial Periods. Some of these photographs assist in developing a three-dimensional image of the TWI in Pune.

Indian Digital Records

These mainly consist of digitised government reports and maps. They help to develop an understanding of the post-colonial and present status of water management and infrastructure. The main government reports that are referred to in this research are as follows:

i. The Census reports by the Office of Registrar General and Census Commissioner, India
ii. The Agricultural Census Reports published by the Agriculture Department, India
iii. The Minor Irrigation Census Reports published by the Ministry of Water Resources
iv. The Regional Plans and Development Plans of Pune published by the Government of Maharashtra

The maps include those that are a part of the Development Plans of Pune. Also, Google Earth Maps have been referred to wherever required. The shortcoming with Government reports is that some of the statistical figures do not tally or seem to be manipulated, especially with sources of irrigation. Therefore, one has to verify these figures from two or more reports.

ii) Field Observation, photographic documentation and measured drawings

One of the objectives of this research is to examine the manifestation of water-related ideas and concepts in a built form. Therefore, it becomes necessary to observe and document TWI as it stands on site. The methods of field observation, photographic documentation and measured drawings as part of field research were utilised for gaining a personal qualitative understanding of TWI. Field research was carried out during three different periods: March 2017, February-March 2018, and November-December 2018. During the field research work, observations were made about various aspects of TWI such as its setting and orientation within the settlement pattern, its architectural features, its construction technique, the level of water retained in it and the way people use its water. In addition to field observations, photographic documentation of TWI was undertaken to generate a permanent record of the observed facts during field observation. In studies related to urban design and architecture, drawings and sketches become a vital tool for conveying information. However, architectural drawings for most of the examples of TWI were absent. Therefore, measured drawings of those examples for which drawings did not exist were made to understand their setting, scale and proportions. Field observation, photographic documentation and measured drawings also helped to cross-verify the information present in the various historical documents surveyed before.

iii) Semi-structured expert interviews

Interviews are not a primary and principal source of information in this research. However, the need for the interview method was felt for crosschecking and verifying the information obtained from the document survey and field research from experts. Further, it clarified some discrepancies in data and probe for additional information. For these purposes, a geologist and two government engineers were interviewed in February 2018. The interviews followed a semi-structured pattern. The topics that required clarification, crosschecking and verifying were identified in advance. At the same time, the interviews were open, allowing new ideas to emerge during the discussion with the expert interviewees. The interviews were recorded and transcribed, and are a part of the appendices.

1.5.8. Using multiple methods and data handling

The use of three qualitative methods and handling multiple data sources was a challenging task. Therefore, the research used triangulation for systematic processing of the varied data and achieving the objectives of the research.

Triangulation, in general, is the use of multiple theories, data sources, methods and investigators within a single study for understanding a particular phenomenon in a better way (Mathison, 1988, p.13; Hoyo and Allen, 2006, p.42). This research uses two types of triangulations: method triangulation and data triangulation for conducting analysis. Methods triangulation refers explicitly to the use of multiple methods, usually qualitative and quantitative to understand a particular phenomenon by overcoming the biases that come from any single method (Heale and Forbes, 2013, p.98) However, this research did not employ any quantitative method of data collection. It used three qualitative methods of data collection, mainly i) document review, ii) field observation and iii) semi-structured expert interviews, as mentioned before. Similarly, data triangulation refers explicitly to the use of multiple data sources to gain a deeper understanding of the subject (ibid). Within the method of document review, data were mainly obtained from the three sources mentioned before: i) Ancient Indian records, ii) British-colonial records, and iii) Indian Digital Records. These multiple methods and data sources were used for fulfilling different objectives of the research as indicated in Table 1.2.

Table 1.2: Use of Triangulation

Objective	*Step*	*Methods used*	*Data used*
To understand the conceptualisation of water in the ancient culture of Pune.	Finding the concepts and ideas about water	Document Review	Commentaries on ancient Scriptures
To understand the working of TWI within the physical and cultural context of Pune.	Identifying TWI	Document Review	British Gazetteer, Office records of Peshwe rulers
	Understanding the architectural and design principles	Document Review Field Research (Measured drawing) Expert Interviews	Shilpa Shastras, Maps: Poona City Survey
To investigate the reasons behind the decline of TWI.	Understanding the Colonial and Post-Colonial policies	Document Review	India Office Records

Source: Author

Thus, as seen in the figure, a combination of different methods and data sources helped in gaining a better understanding of TWI. For instance, data sources such as the Gazetteer of the Bombay Presidency sometimes just mentioned the existence of TWI at a particular place. It did not contain detailed information about aspects such as the size, construction features, and detailing of the TWI. This information was obtained during field research by measuring the water structures present of the site. Similarly, data triangulation helped in crosschecking data obtained from different sources. For instance, the information about who built a particular TWI gathered from the review of ancient Indian sources was used to cross-check the same information present in the Gazetteer of the Bombay Presidency. In this way, both method and data triangulation helped in gaining a more in-depth insight into TWI.

1.5.9. Research scope

This research does not attempt to present a comprehensive collection of the entire range of TWI found in Pune district, nor does it try to present a detailed historical account about the evolution of TWI. Instead, this research attempts to examine a few examples of TWI for developing an in-depth understanding of its location-specificity and sensitivity to the physical and cultural conditions of Pune. While doing so, the research focuses on TWI that was in the domain of common people where the primary motive was to fulfil the water requirement for domestic and irrigation purpose. As a result, the research does not indulge in a discussion on TWI such as ornamental pools and fountains, which were exclusively designed for aesthetic and recreational purposes.

While arranging the various examples of TWI, chronological order has been followed to situate them in the prevailing socio-political conditions at that time. For this purpose, the research engages only in a brief discussion about the socio-political aspects necessary for developing a better understanding of TWI amidst changing socio-political conditions. An in-depth analysis of the political, social, and managerial issues of TWI is not within the scope of this research. Similarly, considering the limited timeframe for carrying out this research, the aspect of wastewater management is not taken into consideration.

1.5.10.Relevance of Research in Water Infrastructure Debates

Along with water being a critical natural element, water infrastructure is one of the many networked critical infrastructures. Lukitsch et al. (2018) define it as,
Critical infrastructure is infrastructure which is needed to keep running other major technical and social systems or which is needed to provide goods or services that are considered vital to the functioning of modern society. (Lukitsch et al., 2018, p.12).

According to Egan (2007) infrastructures are critical if they:— i) help in the smooth running of routine functions, ii) cannot be substituted easily, c) cause significant harm in case of a sudden breakdown, and d) they are embedded in integrated systems (Egan, 2007, p.5). Similarly, Fekte (2011) judges infrastructures as critical based on three criteria:

i) <u>Critical proportion</u>: number of critical nodes of infrastructure, spatial extent, reach, rareness and the impact on people and economy in case of failures.
ii) <u>Critical time</u>: duration of the outage, speed of onset, time of recovery, etc., and
iii) <u>Critical Quality</u>: quality of services delivered. (Fekete, 2011, pp.18-19).

Similarly, various other authors consider critical infrastructures to be those that have a high level of interdependencies, tight coupling and their potential to cause harm and impact the functioning of modern society in case of a breakdown is high (Boin and McConnell, 2007; Bruijne and Eeten, 2007; Vleuten et al., 2013)

If we consider these criteria, water infrastructure no doubt is a critical infrastructure. However, defining the criticality of water infrastructure from this perspective is problematic for several reasons. Firstly, all these criteria consider infrastructures critical from the 'notion of failure'. Such a perspective determines the criticality of infrastructure based on its impact on the society in case of a failure, which is useful for risk analysis and identifying the weak points and linkages in infrastructures. However, it does not recognise that technical infrastructures may fail occasionally and attempting to avoid failure entirely by the use of unsustainable technological solutions may add up to the widespread ecological problems. This observation particularly applies to water infrastructure. The attempt of providing uninterrupted water supply to cities, agriculture and industry by use of modern technology without considering the actual water available in nature has caused several ecological problems, as discussed at the beginning of the chapter.

Secondly, discussions on criticality primarily focus on technology. Herein, the focus is mainly on the different systems components, their linkages, weaknesses, interdependencies, and so on. Again such an analysis lacks the understanding that infrastructure is not merely technological but a combination of natural and technological. By taking the case of water infrastructure, we would realise that it is not only the dams, water treatment plants, pipes and taps that make water infrastructure but also water which is a natural element. Therefore, while analysing the criticality of infrastructure as a whole, it is essential to consider the technical as well as the natural components.

This research deviates from the discussions on criticality focused on the aspects of failure and technology of infrastructures. Instead, it takes a sociocultural perspective on water infrastructure for understanding the way criticality emerges from the history of Pune. It analyses how various communities have considered water infrastructure as critical due to collective preferences. By taking such a perspective on water infrastructure, it attempts to broaden the current understanding of criticality in water infrastructure as follows:

Firstly, by viewing water infrastructure within the disciplines of history and culture, the research identifies various other socio-cultural issues related to water such as water scarcity, water inequity and power relations that require equal attention along with water infrastructure failure. As pointed out by Nawre (2019), these water-related problems are equally critical and cannot be addressed in isolation. Solving these problems, along with the issues of water infrastructure, could also lead to more considerable societal improvement.

Secondly, by situating water infrastructure within history and culture, the research attempts to gain an insight into how people have responded to criticality through their actions. The long historical timeframe is used to investigate the way people built water infrastructure following the prevailing local climatic, topological and socio-cultural conditions. Such a long time scale of observation helps to distil application-related knowledge to handle criticality and face the challenges of natural disasters (Schenk, 2015, p.83).

The next section presents the chapter outline and briefly discusses the contents of each chapter.

1.5.11.Chapter outline

This research is divided into six chapters. Following this chapter of introduction, *Chapter 2* discusses how water has been conceptualised in ancient Hindu Culture. It further outlines how the existing conceptualisation transformed during the Deccan Sultanate, British Colonial and Post-colonial periods. The ideas, beliefs and values related to water form the basis for understanding the TWI. Thus, the chapter does not attempt to give an account of the physical features such as climate, topography, geography and hydrology of Pune but instead discusses how humankind has perceived these features and shaped TWI.

Chapter 3 discusses the TWI built during the Hindu Period from 17th century B.C. to 14th century A.D. The TWI of this period has a strong sacred value attached to it. The chapter begins by discussing the archaeological evidence of a river diversion system that existed during the 17th century B.C. at Inamgaon. Following this, it presents different types of surface and rainwater harvesting structures in chronological order. These structures include podhis and taakya (rock-cut cisterns), and barav (stepped water tank). Further, the chapter discusses specific water-lifting devices used during the period. The chapter concludes by discussing the multi-functionality of water structures, which makes them valuable.

Chapter 4 discusses the TWI built from 14th to 18th century A.D. During the 14th century, Deccan Sultanates coming from Persia invaded Pune and ruled over it for the next two hundred years. Later the native Maratha and Peshwe[12] rulers overthrew their rule. During this period, one can observe a Persian influence on TWI of Pune. The chapter first discusses how the transfer of qanat building technology (underground aqueducts) took place from Iran to India. It then explains how the Deccan Sultanate rulers adapted the technology to construct nahars in Pune. It then discusses in detail the nahars, talavs (lakes) and kunds (stepped water tanks in temples) built by the Peshwe rulers in Pune. The chapter concludes by pointing at the landscape transformations brought about by nahars in Pune.

[12] The Maratha Rulers were group of warriors who attempted to end the rule of the Deccan Sultanates and establish self-rule and self-governance. Their rule over Deccan existed predominantly from 1630-1714. They were later succeeded by their prime minters known as the Peshwe from 1714-1817 (Sowani, 2011, p.50).

Chapter 5 explains the reasons for the decline of TWI in Pune during the colonial (1818-1947 A.D.) and post-colonial (1947 onwards) periods. It first discusses how the British failed to maintain the TWI, which led to its decline. The British motive of gaining productive control over India's water resources led to the construction of large dams and canals in India. The chapter then discusses the impact of these large dams on traditional water management practices in Pune. It then explains how the Indian Government continued the trajectory of British and built large dams as symbols of India's progress and modernity. The chapter concludes by explaining the adverse effects of large dams and the need to follow an alternative path of water management

Chapter 6 begins by restating the research objectives and summarising the key findings from the previous chapters. It then discusses the importance of culture and TWI in water management and tackling current water-related problems. The chapter concludes by giving specific broad recommendations about the possible ways of learning from TWI and strengthening the human-water relation.

2. Cultural Understanding of Water

This chapter aims to understand the way water has been conceptualised in the ancient Hindu Culture of India. It explores the various ideas and beliefs that have shaped the traditional water infrastructure, people's attitude and relation with water in India and especially in Pune. It also discusses the extent to which the conceptualisation changed during the Deccan Sultanate, British-Colonial and Post-Colonial periods resulting in the construction of modern centralised infrastructure. The chapter ends by summarising the changing ideas about water. The summary serves as the basis for understanding the TWI discussed in the succeeding chapters.

2.1. Introduction

Water, as a part of nature, is considered holy in almost every pre-modern culture of the world. Almost every culture has ancient myths and legends about river gods, goddesses, dragon, leviathans, and other supernatural mystical beings. These myths and legends are part of many nature religions (Strang, 2011, p.214). Similarly, in India, rivers, rainfall and the numerous water bodies are considered holy by the Indians. Geographically India is traditionally described as Bharat – the land to the north of the Sindhu (Indian Ocean) and south of the Himalayas (Singh, 2017a, p.8). Thus, water gives cultural identity to India and many other countries.

This chapter aims to extract some of the key ideas and concepts about water that are a part of the ancient Indian culture, described in ancient Indian myths and legends. According to Masse et al. (2007), myths and legends are orally transmitted poetry or prose, mostly semi-historical combining realism with supernatural and mythic elements which are believed true by the cultures in which they are told. They often contain historical-cultural records of geographical and geological processes that need to be extracted for understanding natural events that occurred in the past (Masse et al., 2007, p.9,25). Concerning this research, the purpose of extracting these ideas and concepts is to understand the way water has been conceptualised in Indian Culture that has shaped the design of Traditional Water Infrastructure (TWI) in India

In the Indian context, the myths and legends are part of the ancient Indian scriptures especially, the Vedas and Puranas. Vedas are a form of revealed knowledge handed down from generation to generation, through oral transmission (Bose, 1971, p.14). Apart from several hymns on astrology, meteorology, geology, medicine, music and several other disciplines, they also contain many hymns about rivers, rainfall and water bodies. Similarly, Puranas are ancient commentaries on ancient Hindu philosophy, culture, geography, ethics and theology (Mani, 1975, p.vii). Thus, both Vedas and Puranas are good sources for extracting water-related ideas and concepts prevalent in Hindu Culture.

However, as culture is dynamic, it is subject to adaptation, alteration, and even destruction due to changing socio-political and economic conditions, and influences coming from other cultures. Therefore, this chapter also aims to identify the extent to which conceptualization of water in Hindu Culture undergo a change during the three significant periods of timeframe discussed in Chapter 1: the Deccan Sultanate Period (14^{th} to mid-17^{th} century), British Colonial Period (1818-1947) and Post-Colonial Period (after 1947). Within each period, it attempts to answer the following questions:

What were the ideas and perceptions of people about water?

How did these ideas and perceptions influence the socio-cultural and religious practices and water infrastructure of people?

How did water infrastructure change with changed perceptions of water?

The periods mentioned here are for convenience purpose for facilitating the discussion on TWI. They are fluid. The change in the conceptualisation of water is not sudden but gradual across the periods. The remaining chapter is divided into four sections. *Section 2.1* explores how ideas and beliefs in Hindu Culture have shaped the traditional water infrastructure of Pune. It discusses the ideas about rivers and rainfall that prevail amongst people as the primary sources of water. It sheds light on some of the practices and rituals related to water, which help in understanding TWI. In the end, it briefly discusses the concept of meritorious donations that enabled people to build and donate several water structures.

Section 2.2 discusses the transfer of Persian technology of constructing qanats (underground aqueducts) into India through the Deccan Sultanates that influenced the Peshwe rulers to adapt it for constructing nahars in Pune. Besides, it also discusses the role of the Peshwe rulers, saints and ordinary people in building and maintaining the TWI in a collaborative way.

Section 2.3 explores the British Empire's perception of water, its idea of science and technology, leading to the construction of large-scale centralised water infrastructure in India. In continuation, *section 2.4* discusses the concepts of modernity and progress that influenced the foreign-trained Indian nationalist and engineers to continue the trajectory of the British Empire of constructing large-scale centralised water infrastructure. The chapter concludes by summarising the changed perception about water across the four identified periods that serves as the basis for understanding the traditional water infrastructure.

2.2. Sacred Water: Conceptualisation in Hindu Culture

The Hindu culture sees water with deep reverence. The ancient Hindu mythology considers water to be the container of life, strength and eternity (Singh, 1994, p.210). Myths also believe water to be the primordial substance through which the world came into existence (Hegewald, 2002, p.11). Water being the essence of life, is considered to be divine. It is equally valid for the two essential sources of water – rivers and rainfall.

2.2.1. Sacrality of rivers, river sources and river confluences

Sacrality of rivers

Similar to most pre-modern cultures, the ancient Indian Culture flourished along the banks of rivers. The old religious texts of India describe India as the land that is watered by the seven rivers – Sindhu (present Indus), Saraswati, Ravi, Vyas, Chenab, Jhelum, and Sutlej (Law, 1944, p.2). The word 'Hindu Culture' derives its name from the River Sindhu. As per popular Hindu belief, most of the rivers have descended on earth from heaven.

People imagine the River Ganga as the daughter of the snow-clad mountain Himalaya. According to the popular legend, Bhagirath did a long penance for requesting Brahma – the creator of life to send the Ganga on earth for the well-being of humankind. However, the velocity of Ganga was so high that it would have eroded the earth's surface. Therefore, Shiva held the Ganga in his hair locks to reduce her velocity and released her gradually to nourish the Indian plains.[13] Such legends are often symbolic. One needs to decipher the hidden symbolism of such legends for understanding specific geographical facts. In case of the legend describing the descent of Ganga, the hair locks of Shiva symbolise the dense vegetative cover of the Himalayas, which cuts off her velocity and prevent soil erosion (Shiva, 2002).

Figure 2.1: Popular Calendar image in India showing descent of Ganga.
Source: www.mygodpictures.com, accessed on 03-06-2019.

[13] The legend describing the descent of River Ganga is part of the Markandeya Purana. Puranas are part of oral history of India that contain such legends (Darian, 1978, p.59).

Similar legends exist about the rivers in Pune. The Bhima is the principal river in Pune. It originates in the hilly terrain towards the west of Pune known as the Western Ghats. As it traverses through Pune from west to east, it is joined by seven other smaller rivers – Vel, Ghod, Bhama, Indrayani, Mula, Mutha, and Nira which form its tributaries (GBP-XVIII, Part-I, 1885, p.6) Together these rivers form the Bhima River Basin (refer Fig 2.2). There are two interesting legends about the rivers Bhima and Mutha. According to a popular legend, Lord Shiva was relaxing after defeating a demon. A king named Bhimak prayed to him to change the sweat on his forehead into a river. Lord Shiva accepted his prayer, and since then, the sweat on Shiva's forehead started flowing in the form of a river (GBP-XVIII, Part-III, 1885, p.120).[14] The place where Shiva rested is identified as the current Bhimashankar, which is the source of Bhima and an ecological reserve with rich biodiversity.

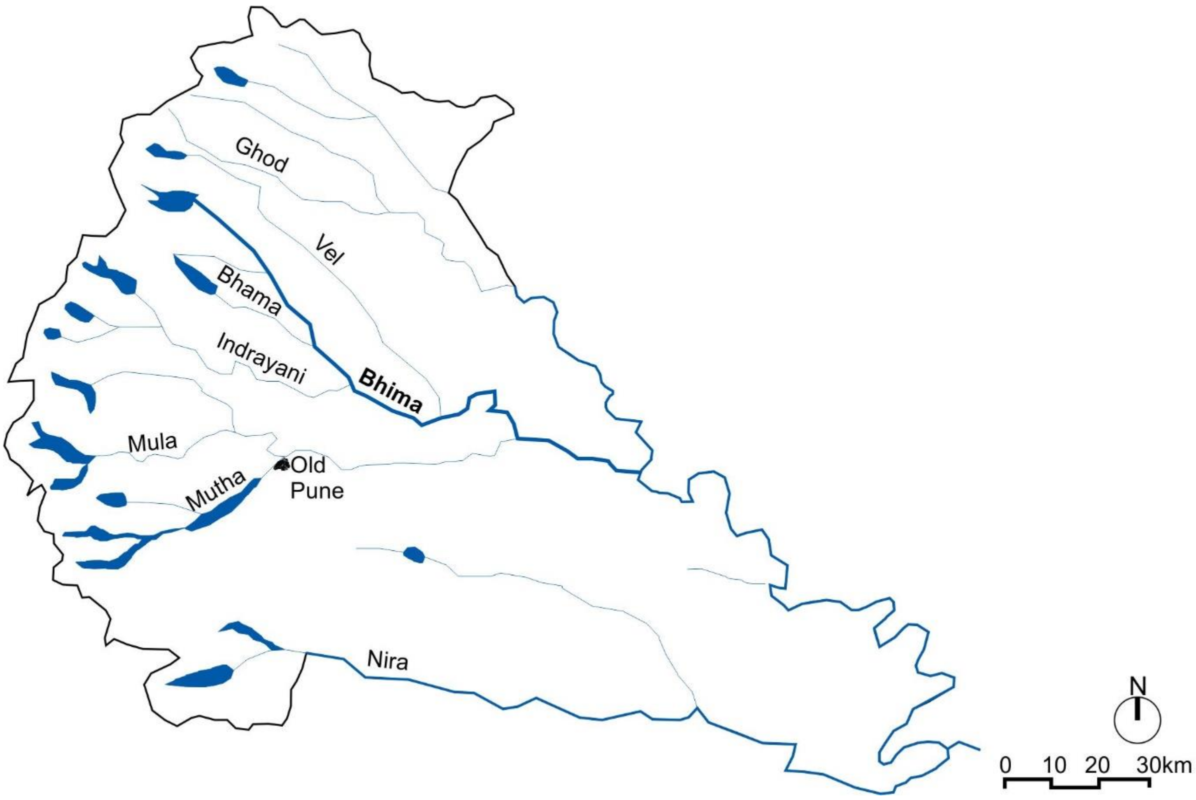


Figure 2.2: Map of Pune district showing the different rivers.
Source: Adapted from PMRDA, 2016.

A similar legend explains the origin of the Mula and Mutha Rivers. According to the Myth, a king named Gajanak was into deep meditation. His meditation made Lord Indra – the ruler of heaven, restless. He felt that through his meditative power, Gajanak would attempt to capture his heaven. Therefore, to break his meditation, Indra sent two *apsaras* (beautiful nymphs) to break Gajanak's meditation. When they tried breaking Gajanak's meditation, he cursed them

[14] The Gazetteer of Bombay Presidency (1885) does not mention the original source of this legend. Since, such legends are transmitted orally, it is probable that the British writers heard and documented the legend from the people of Bhimashankar.

that they would flow permanently on earth in the form of two rivers – Mula and Mutha and would attain liberation from the curse only when they meet the Bhima (Dandekar, 2015).

Along with the legends, there are many ideas and beliefs about rivers coming from the tribal culture of indigenous communities. These ideas and beliefs in the form of social restraints, religious taboos, nature worship, etc. are part of Indigenous Knowledge (IK) or Traditional Ecological Knowledge (TEK) of a culture. (See Berkes et al., 1995; Pierotti and Wildcat, 2000).

The indigenous communities in India known as the *Adivasis* consider most of the rivers as feminine, fertile and sacred (Bokhare, 2005, pp.308-313). They worship rivers in their natural form as well as in their personified forms as goddesses or divine mothers. The daily life of people is attuned to the natural flooding pattern of rivers. When the rivers flood, they yield abundant fishes to the people. When they become relatively dry, people cross them by canoes. Adivasis such as the Gonds respect the natural flooding patterns of rivers. When a river floods, they consider it to be pregnant and do not cross it by canoes. Such personification or anthropomorphism of rivers expresses the Adivasis' total oneness with nature, especially the element water and their effort to relate to the metaphysical world (ibid).

Sacrality of river sources

In Adivasi culture, we also observe the practice of protecting the source of rivers from any pollution and human alteration. Ghate and Datar (2014) and Pawar et al. (2016) explain the common prevailing practice in many Adivasi communities of protecting the groves around river sources as sacred groves known as *Devrais*. The Adivasis consider devrais as sacred adobes of Gods and protect them from any human interference. Many such groves contain temples, one of them being the Shiva temple at Bhimashankar near the origin of River Bhima. Other forests contain smaller temples of local deities. Once such Devrai is in the Vegre Taluka of Pune near the source of River Mutha. It has an area of two acres dedicated to the deity *Somebhairavnath* (a local form of Lord Shiva) (Pawar et al., 2016, p.59).

The close study of such Devrais reveals that they are repositories of rich biodiversity containing several rare species of flora and fauna (Ghate and Datar, 2014, p.247; Pawar et al., 2016, p.58). The religious and ritualistic beliefs of the Adivasis bind them to the deity, and they protect the Devrai. Protecting the Devrai ultimately leads to the protection of river source and prevention of any pollution at the source, thereby highlighting how religious beliefs and taboos of indigenous communities have an embedded ecological awareness of biodiversity conservation.

Sacrality of river confluences

Along with rivers, Hindu Culture also considers river confluences as sacred. The most sacred of the river confluences in India is the confluence of the Ganga, Yamuna and the mystic Saraswati at Prayag (Kane, 1973, Vol. IV., p.557). There are many other river confluences in India, which people consider as sacred such as the Narmada, Orsang and Saraswati confluence at Chandod, Gujarat and the Venna and Krishna confluence at Mahuli, Maharashtra (Sagare, 2018, pp.17-18).

There are two famous river confluences in Pune. One confluence is at the village Tulapur popularly known as the *Triveni Sangam* (confluence of three rivers) where the rivers Bhima, Bhama and Indrayani meet each other. Another one is at Pune where the Mula and Mutha meet each other. The medieval settlement of Pune in 8th century A.D. developed near the confluence of Mula and Mutha and was considered a holy place (Gadgil, 1945, p.3). Its holiness is evident from the etymology of the word 'Pune'. An ancient copper plate belonging to the period of Rashtrakuta rulers (8th – 10th centuries A.D.) mentions Pune as *Punya* vishaya.[15] According to Oturkar (1951), Punya is a Sanskrit word, where the root 'pu' means pure, sacred or holy. Since the location of a town near a confluence is considered holy in Hindu Culture; Pune attained the character of a holy town (Oturkar, 1951, p.8). Even later, in the 16th century, Pune was known as a holy town *Purnanagar* (Gadgil, 1945, p.3). In addition to the rivers Mula and Mutha, three streams – Nagzari, Manik Nala and Ambil Odha flowed through Pune. Out of these three streams, the Nagzari was considered holy. Two temples, Nageshwar and Punyeshwar, existed along the banks of the Nagzari (Sowani, 2017, p.39). Poetry composed by Eknath (16th century A.D.) describes Pune as a sacred place near the Nagzari with these two temples along its banks (ibid)[16].

After discussing the way rivers, river sources and river confluences gain cultural and religious significance; the next section discusses the way rainfall is conceptualised in the Hindu Culture.

2.2.2. Rainfall as Lord of the Sky

Along with rivers, there is a deep reverence for rains in India. Kapoor (2000) describes how ancient Indians have personified rainfall as the god of heaven. In popular Hindu belief, Indra and Varuna are the two gods associated with rain and water. Indra is more popular and often mentioned in the Vedas. He is portrayed as the lord of the sky who has an army of elephants. These elephants were metaphors for different types of clouds such as lightning sender, thunder

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[15] The copper plate dates back to 758 A.D. It mentions that the Rashtrakuta King Krisha donated the Bopkhel village to a person named Pugadi Bhat. In this copper plate, Pune region is mentioned as Punya Vishaya. It also mentions that the River Mula flows along the south of the village, which is geographically a correct description. The original Sanskrit text on the original copper plate is,
पुण्याविषयान्तर्गत बोपलखळुग्रामः
यस्य पूर्वतो कालसः
दक्षिणतः नदी मूईला
पश्चिमतः दर्पपूडिका
उत्तर तो भेऊसरी ग्रामः (Sowani, 2017, p.16).

[16] Eknath has given the following description of Nagzari in Marathi,
दक्षिणे पुन्येश्वरो देवो
नागेश्वर महादेवो
मूळपीठी नागेंद्री पहा वो
त्रिवेणीरूपे वाहातसे (Sowani, 2017, p.39).

bearer, black, white, blue, rumbler, growler, etc. (Kapoor, 2000, Vol.2, p.940) The main elephant whose name is *Airavat* means watery. Indra is also portrayed as the one who is exceptionally insecure about losing his dominance of the sky to other heavenly bodies. He often loses his dominance to other celestial bodies' period and regains his dominant position after defeating them in due course of time. This imagination of Indra represents the monsoon cycle wherein the season of monsoon is the time when Indra is dominating and the other seasons wherein the other celestial bodies are dominating. Ancient Indian scripts also refer Varuna as the god of ocean, clouds and rain. The scriptures mention him as the one who has hollowed out channels of water for the benefit of humankind (Kapoor, 2000, Vol.5, p.389).

Figure 2.3: Indra on Airavat: Sculpture on Lakshmi Narayan Temple built in 1246 A.D.
Source: Hegde, 2017.

When we carefully examine the personification of rainfall as Indra and his insecurity about losing dominance in the sky, we can relate the imagination with the monsoon cycle in India. The ancient Hindu calendar contains 12 lunar months and a group of two months formed a season (Srinivasan, 1975, p.5). Thus, traditionally, there were the following six seasons:

Table 2.1: The Indian seasons according to the Hindu Calendar.

	Indian name	Season	Duration
1	*Vasanta*	spring	March-May
2	*Grishma*	summer	May- July
3	*Varsha*	rain	July- September
4	*Sharad*	autumn	September- November
5	*Hemanta*	winter	November- January
6	*Sishira*	cool season	January-March

Source: Adapted from Srinivasan, 1975.

Thus, Varsha is the only season of rainfall in most parts of India, i.e. the period from June to September. Within these four months, 75% of the rain occurs in 50 days and less than 100 hours as already pointed out in Chapter 1 (See p. 1). This rainfall pattern seems to have influenced the imagination of ancient Indians who gave it the form of a myth.

Apart from this personification of rainfall as Indra and Varuna in the Vedas, specific scientific texts such as the Arthashastra of Kautilya (300 B.C.- 100 A.D.) also describe rain gauges for measuring rainfall (Srinivasan, 1975, pp.148-153). The rain gauge was known as *varshamana,* and the unit of measurement was *drona.* One drona is equivalent to 50.8mm. Based on the actual analysis of rainfall across different parts of India, Kautilya classified the entire area of India into six rainfall zones. He calculated the rainfall in Pune belonging to the *ashmaka* zone as 13 ½ dronas (ibid). After converting dronas into millimetres, the rainfall of Pune works out to be 685.9mm. This quantity is very close to the average annual rainfall of 715 mm, as worked out by the Pune Meteorological Department (IMD, 2018). Thus, rainfall permeates the ancient culture of India and Pune. On the one hand, it attains the personified form of God, and on the other hand, it gains importance in ancient meteorological sciences of India.

To summerise, the ideas and concepts about water present in the Hindu mythology transcend beyond their sacred character and become valuable information sources for understanding the traditional knowledge about ecology, geology and meteorology in ancient Indian culture. We can observe that water has been revered and personified in Indian Culture, and there is a strong human-water relation. The next section discusses the way this idea of sacredness reflects in the socio-cultural and religious practices of people and gains a material form through water structures.

2.2.3. Socio-cultural and religious practices associated with water

The concept of tirtha and the practice of ritualistic bathing

The idea of water being a sacred element is strengthened further by the idea of taking a ceremonial bath in the holy rivers and other natural water bodies. Although people consider water a sacred element, the water within specific geographical setting becomes more sacred. According to Kane (1973), certain places in India become more sacred on three grounds. Firstly, due to their unusual natural characteristic. Secondly, due to some peculiar striking water feature. Thirdly, because some holy sages had stayed at such places or bathed in the water bodies (Kane, 1973, Vol.IV., pp.554-555). Thus, when a site or locality meets any one or more of the three criteria, people identify it as a *tirtha*. Therefore, he defines a tirtha as

"[...] a locality or spot or expanse of water which gives rise to the accumulation of righteousness (merit) owing to its peculiar nature […]". (Kane, 1973, Vol.IV, p.555).

The geographical speciality of the tirthas also gave rise to the religious practice of visiting the tirthas and experiencing their unique geographical setting. Tirthas spread geographically across India. Thus, when people had to reach a particular tirtha, they had to travel long distances. During their travel, they experienced the diversity and uniqueness of different cultural landscapes in India (Singh, 2017b). Furthermore, most of the tirthas in India were difficult to traverse located on top of mountains and in remote locations. Therefore, rather than reaching and doing something at the tirtha, the journey itself transformed a person.

Apart from the geographical significance of tirthas, they have a metaphysical significance. Eck (1981) states that tirthas are thresholds that link the earthly world with the mystic heaven. It is a place of launching oneself on the journey from earth to heaven (Eck, 1981, p.328). Due to their metaphysical significance, people considered bathing in tirthas far more auspicious than bathing in other water bodies. As explained by Hegewald (2002), ritualistic bathing prepares a person internally for crossing a border. Immersion of the body into water is symbolic of death and reappearing from water is symbolic of gaining rebirth. In this case, death symbolises the dissolution of one's sins and pollution, and rebirth symbolises that one is pure and in the right frame of mind for entering the sacred terrain of the divine (Hegewald, 2002, p.25). At the same time, it is significant to note that ancient religious texts do not encourage mere bathing in rivers for getting rid of one's sines. They state that truthfulness, self-control, charity, contentment, sweet speech, knowledge, and patience are virtues that are equivalent to tirthas. They consider the highest tirtha to be the purity of mind.[17]

People also linked ritualistic bathing with the occurrence of special cosmic events such as favourable constellations of stars (Hegewald, 2002, p.32). During the existence of such cosmic

[17] Kane (1973, Vol.IV., p.563) mentions that Puranas such as Skandapurana, Kashikhanda 6, Padma, and Uttarkhanda 237 consider certain virtues as mental tirthas.

events, tirthas attain special significance. Religious fairs and bathing festivals are organised at the tirthas during such special cosmic events. For example, in Pune district, Jejuri is a pilgrimage town famous for the temple of Khandoba. In the months of November-December, there is a unique festival in Jejuri. The pilgrims who come to visit the temple during the festival take a bath in a pool known as the Malhar Tirth before entering the temple (GBP-XVIII, Part-III, 1885, pp.135-136).

In short, the concept of tirtha and ritualistic bathing emerged to connect the ancient Indians to the diverse geography of India. At the same time, attaching the idea of ritualistic bathing at such tirthas encouraged people to engage with water. Another practice that was a part of Indian Culture was patronising and constructing water storage structures for obtaining religious merit.

The practice of patronising and constructing water storage structures

The religious concept of attaining spiritual merit by performing sacrifices and acts of charity has played a vital role in encouraging people to build water storage structures (Kane, 1974, Vol. II, Part II, p.890). The Vedas and Puranas mention various acts of charity such as donation of money, land, cows, and so on. In these charitable acts, the gift of wells and tanks has been given the highest value amongst all and is believed to earn the donor the highest spiritual reward.[18]

While donating a water structure for the common good of the society, the donor had to follow two rules. The first one was that the donor must completely give up his ownership over the water structure. The second one was that the water structure should be in the more considerable interest of society and not benefit a few individuals alone (Kane, 1974, Vol.II., Part II, p.893). Specific rites to be performed such as offering flowers, rice, etc. to water and surrounding landscape while constructing and donating water structure have been laid down in the religious scriptures. After performing these rites, people considered the water structure sacred and fit to be used for its intended purpose. Performing these rites of donation on special cosmic events such as solar eclipses, lunar eclipses, summer and winter solstices was believed to fetch special spiritual rewards for the donor (ibid). The concept of donation encouraged several kings, noblemen and other wealthy people to construct podhis, taakya and barav, and dedicate them to the society. Several stone tablets near the podhis and barav of Pune mention the names of the donors who donated the structures for the common welfare of the community (discussed in further detail in chapter 3).

[18] The act of donation was a part of one's moral duties known as ishta purta. The verses from ancient text Krutyaratnakar have the following verse:
इष्टापुर्तौ स्मृतौ धर्मौ श्रुतौ तौ शिष्टसमतौ प्रतिष्ठाद्यं तयोः पूर्तामिष्टं यज्ञादि लक्षणम् मुक्तिमुक्ति पदं पुर्तमिष्टं भोगार्थसाधनाम्
(Kane, 1974, Vol. II, Part II, p.890).

Preparedness for rainfall uncertainties

The ancient text Krishiparashar written by Sage Parashar[19] is a detailed account of different ways to predict the rainfall, based on the observation of clouds and star constellations. Besides predicting the rainfall, the text contained several chapters on the appropriate time to harvest, care to be taken while harvesting and the ways of being prepared for rainfall uncertainty. It has an entire section called *Jalrakshanam* on the importance of water storage, especially if one has to cultivate crops during the winter months.

Two verses from the chapter say that

The person who does not store water for the winter months is a fool. It further states that the way a family head would take care of women in the family; similarly, one should take utmost care of the water stored for irrigation (Krishiparashar, Chapt.31, Verses 196-197).[20]

Thus, one can observe that along with a reverence for water in the society, there was awareness about water conservation and being prepared for unforeseen natural calamities such as droughts.

In short, we can observe the way ideas about water being a sacred entity translate into the cultural and religious practices of people. These practices, in the form of rituals, ensured that society always remembers the value of water. The next section discusses the way ideas about water manifest into the built form of water structures.

2.2.4. Cultural landscapes reflecting the ideas about water

Even though the ancient Indians revered water, they had to divert the rivers for irrigation and construct water structures for storing rainwater. There was a considerable alteration of the natural landscape into the cultural landscape while making provision for irrigation. The cultural landscape near rivers is known as *Nadimatruk*, and the cultural landscape away from rivers depending on rainwater harvesting is known as *Devmatruk* (Bokhare, 2005, p.306; Morvanchikar, 2018, p.363, 378). Both these landscapes have their distant characteristics as explained further.

[19] The date when Krishiparashar was written is unknown. However, Kane (1973) assumes that Parashar wrote it between 1st and 5th centuries A.D.
[20] The original Sanskrit Verses are
आश्विने कार्तिके चैव धानस्य जलरक्षनम
न कृतं येन मुर्खेन तस्य का शास्यावासना १९६
यथा कुलार्थी कुरुते कुलस्त्रीपरिरक्षनम
तथा संरक्षयेद वारि शरत्काले समागते १९७ (Krishiparashar, Chapt.31, Verses 196-197).

Nadimatruk: River centred cultural landscape

Dependence on rivers is the main feature of the cultures developed along the rivers as already discussed. Although there is a reverence for rivers, people have to build bunds and dams on rivers and lay water channels for diverting and conveying their water. However, the religious ideas about rivers often (not always) play a role in ensuring that there is minimum interference in the natural courses of rivers (Bokhare, 2005, p.310; Paranjpye and Paranjpye, 2005, p.333). Similarly, the idea of 'water-sharing' was predominant while distributing the river water (Paranjpye and Paranjpye, 2005, p.337).

In Western Maharashtra, people built small check dams that did not stop the flow of river unlike modern dams, but instead diverted the river water to their fields and released the excess water back into the river. These small dams are known as bandharas and the system of diversion and distribution as *phad* (Patil, 2006, p.117; Dharashivkar, 2018, p.72). This system is existing since 300 B.C. and is still found in some parts of Western Maharashtra (Morvanchikar, 2018, p.219). Due to the sustainability of the system, it continues to survive until today for over two thousand years (ibid).

The Gazetteer of Bombay Presidency (1885) and the Revised Gazetteer of Maharashtra (1954) mention the existence of bandharas in Pune. However, they do not mention the presence of phad system. The archaeological evidence of one of the earliest river diversion system dating back to 1400 B.C. has been found in Pune at Inamgaon. This system is discussed in Chapter 3.

Devmatruk: Rainfall centred cultural landscape

The settlements that came up away from the riverbanks had to depend on the storage of rainwater, surface runoff and groundwater for irrigation purposes. Therefore, in such settlements we observe that people developed a culture of harvesting rainwater and building different water structures storing rainwater (Morvanchikar, 2018, p.379). The beautiful water tanks and stepwells of Rajasthan are excellent examples of water harvesting structures.

In Pune, one can find rainwater and groundwater harvesting structures such as podhi, taakya, barav, talav, and kunds. These structures reflect the idea of sacrality in several ways, starting from their placement in settlements, orientation, design and detailing. The kunds and baravs are mostly oriented along the cardinal axes symbolising their close association with the cosmos (Hegewald, 2002, p.124). They were also placed at the central axes of temples to accentuate their connection with the sacred.

The kunds and baravs also contain images of Brahma, Vishnu, Shiva, Indra, and other deities in the niches of their walls. Herein, the imagination of Indians about natural forces gets a physical form. The deities are also imagined to protect the water structures from evil forces in nature (Hegewald, 2002, p.128).

Thus, the ideas and concepts about rain and water, in general, manifest strongly in case of water storage structures. Chapter 3 discusses these structures and the concepts behind their construction in further detail.

After the 14th century, although the idea of water being a sacred element prevailed, the TWI emerging between the 16th and 18th centuries shows a change of technique. This change was brought about by the Deccan Sultanate dynasties[21] who ruled over Pune and Deccan from the end of 13th century until the mid-17th century. The Deccan Sultanates, who originally came from Persia, had slightly different ideas about water and adopted a new technique for constructing water infrastructure. The next section discusses their ideas and technology, which influenced the Peshwe rulers[22] to build a system of underground aqueducts known as nahar in Pune.

2.3. Water flows to settlement: Influence of Persian technology

During the period starting from the end of the 13th century until the end of the 17th century, certain parts of the Deccan region were under the political rule of the Deccan Sultanates. These dynasties came to Deccan from Persia with the motive to establish their control over the prosperous region of Deccan (Gadgil, 1945, p.3).

2.3.1. Conceptualisation of water in Persian Culture

The Deccan Sultanates coming from Persia had a climatic and geographical context different from India. Most of the Middle-East region has harsh desert-like conditions. The average annual rainfall is 270mm (Ahmadi et al., 2010, p.125; Gholikandi et al., 2013, p.583). Therefore, in ancient times, wherever people found traces of water, they established their settlement there and attempted to create a garden by bringing water through channels. These landscape gardens symbolised paradise of earth. These gardens having geometric patterns were commonly known as *Char Baug in* Persia (ibid).

Water running in the four corners of the Char Baug symbolised four heavenly streams of water. *Anahita* was the goddess of water according to ancient Persian belief (Farahi et al., 2016, p.4). However, we observe that the Persian culture had an appreciation for 'flowing water' and the 'playfulness of water'. Unlike Indians, who built more storage structures, Persians made channels and explored the flow, gusting, cascading and other aesthetic dimensions of water. In the Char Baug, people used water in the form of fountains, cascades, pools, waterfalls and channels as a decorative landscape element (Fekete and Haidari, 2015, pp.87-88).

[21] Alaud-Din Khalji first invaded Deccan in 1294. The Khalji dynasty originally came from Afghanistan. In 1347, Deccan came under rule of Bahamani kings who also came from Afghanistan. Sooner, the Bahamani kingdom split up into five kingdoms: i) Imadshahi (1484-1572), ii) Nizamshahi (1489-1637), iii) Adilshahi (1489-1686), iv) Bereedshahi (1492-1656), v) Qutubshahi (1512-1667). Pune was a part of their territory (Gadgil, 1945, pp.3-4; Sowani, 2011, pp.25-32).

[22] The Peshwe rulers were native Hindu Brahmin rulers who ruled Pune from 1720 until 1818.

Besides the use of water for landscaping, Persians developed a unique technology of building subterranean tunnels known as qanats for bringing groundwater to their settlements (Hodge, 2000, p.36). These qanats tapped water from aquifers in hilly areas and transported it up to the settlements by utilising the natural gradient of the terrain. Transporting water through qanats prevented the loss of water due to evaporation. The water from the qanats was collected into several cisterns in the settlement and used for domestic purposes.

2.3.2. Use of Persian technology for construction of nahars

Thus, when the Deccan Sultanates captured the towns of Deccan such as Ahmednagar, Bijapur, Aurangabad, and Burhanpur, they wondered at the lack of any flowing water. They attempted to adopt the technique of building qanats in Deccan for fulfilling the water requirement of their capital towns. Until then, the Deccan towns did not have such a system that brought water to the settlements. They had irrigation systems of open canals, but such underground systems of domestic water supply were absent until the period of the Deccan Sultanates. In the Deccan towns, the adapted version of the qanats was called as *jahapanhi* or *nahar* (Mate, 1998, p.127). Both are Persian words. The word *Jahapanha* means saviour of the world. Thus, the phrase jahapanhi means the water work built by the Jahapanha, an indicative of the Deccan Sultanate hegemony over Deccan. Creating a sound water supply system was a way for the rulers to display their power and ability to rule over people. The other word nahar means a river and is more frequently used now for denoting the underground tunnels built by the Deccan Sultanates (ibid).

The Peshwe rulers adapted this Persian technique of building nahars for Pune during the 18th century for solving its problem of water scarcity (Mate, 1998, pp.140-141). It is interesting that in spite of coming from Persia, nahars were suitably adapted and well integrated into the physical and cultural fabric of Pune. The Peshwe rulers designed the nahars by carefully studying the terrain of Pune. The sources of water supply were at a higher altitude from which water was brought to the old settlement of Pune by making use of natural surface gradient. Moreover, the cisterns, which collected water from the nahar, were designed in a manner that allowed the people to carry out their daily religious rituals as before (ibid).

A significant point to note here is that building of nahars did not cause a discontinuity in the long-lasting tradition of building rainwater, surface-runoff and groundwater harvesting structures in Pune. This new technology coming from outside was absorbed within the prevailing practices of building water structures. However, the technology did influence the landscape of Pune. We observe the emergence of many fruit orchards and gardens during the Peshwe rule that were watered by the nahars. Similarly, the nahars and cisterns became a part of Pune's identity and image.[23] Folk artists called *shahirs* composed traditional folk songs called

[23] Sowani (2017) has given a detailed description of most of the gardens and cisterns built during the Peshwe Period, which is discussed in Chapter 4.

powadas of Pune. In one such powada, Shahir Ramjoshi mentions people performing religious rituals on the water cisterns of Pune and the way nahars made Pune prosperous.[24]

To summarise, the advent of the Persian culture did not alter the Indian cultural beliefs that revered water and considered it sacred. Nevertheless, Persian ideas about water and the technology of qanat building did influence the design of traditional water infrastructure in Pune during the period of Peshwe rulers. These nahars were well integrated into the physical and cultural landscape of Pune and became an extended part of Pune's traditional water infrastructure.

Due to the TWI built by the Peshwe rulers during the 18th century, Pune experienced steady growth and development. However, in 1817, the British defeated the Peshwe in the battle of Khadki and captured Pune. From 1818 onwards until 1947, Pune was under British rule. The British coming from an altogether different context and with the motive of ruling India had strikingly different ideas about India's water and traditional water infrastructure. The next section discusses how the British perceived water and how did their perception affect the traditional water infrastructure of Pune.

2.4. Productive water: Control by the British

The political rule of the British over India lasted from 1757 until 1947 for a period of almost two hundred years. Pune was under the control of the British from 1817 until 1947 (GBS-XX, 1954, p.i). For understanding the impact of British Culture on the traditional water infrastructure of Pune, it is necessary to have an idea about two aspects. Firstly, the common perception of water and nature in Britain, especially after the 16th century and secondly, the outlook of the British towards the water resources in India.

Similar to the ancient Hindu Culture in India, the old European pre-Greco Roman culture revered water and considered it sacred. Many legends in the early European Culture discuss Water Gods, nymphs, fairies, water-related supernatural beings, and so on (Strang, 2011, p.214). This culture imagined humans to be a part of the surrounding natural forces. However, gradually during the Greco-Roman culture, the idea of a hierarchal system emerged (Callicott and Ames, 1989, pp.3-6). This culture believed that humans were superior to all living beings and it was their duty to bring order within nature at God's command. Consequently, the concept of water being a source for achieving human comfort and luxury became popular during the Roman Empire. Therefore, the Romans built extensive aqueducts that symbolised human power and control over nature. Illich (1985) mentions that in 100 A.D., the Roman Empire

[24] The original powada in Marathi is,
वसविले त्यांनी पुणे शहर टुमादारीचे
जागोजाग बांधले दाट नळ पाण्याचे
ठायी ठायी शोभती हौद एक फर्म्याचे
धनी कृपावंत कल्याण करी रयतेचे
The powada is displayed at the Peshwe Museum at Parvati. The date of the powada is unknown.

used ten times more water than what London, Paris and Frankfurt used in 1823, highlighting the luxurious life of the Romans (Illich, 1985, p.37).

Gradually, the Enlightenment Movement and the scientific revolution in the 16th century had a profound impact on the perception of nature in Europe and especially Britain. New scientific discoveries focused on achieving human comfort and luxury by controlling nature. Continued expansion of human knowledge of the environment for controlling nature was considered a prerequisite for becoming modern and progressive (Callicott and Ames, 1989, pp.5-6). Development of science led to the simultaneous development of a mechanistic worldview of looking at nature. In the case of water, it was no more a mythical and cultural element but a commodity H_2O to be exploited to the fullest (Illich, 1985, p.76). Even the geographical conditions in England favoured such exploitation of water. The steady flow of English rivers and little sedimentation made them favourable for navigation and generating energy by using the water wheel. Thus, in England by the end of the 18th century almost every river was altered, channelised and made navigable. The water wheel technology became extremely popular in England to power the textile and metallurgy industry, which became a significant technological advancement in England during the 17th and 18th centuries (Tvedt, 2010, p.34).

With this industrial background back in England, the British entered India as traders in the 17th century. The corporation of the traders was known as the British East India Company (EIC). The EIC was a mixed private-state company which had around 215 private stakeholders (Sahni, 2013, p.317). It had the backing of the British Crown. The main motive of the EIC was profit maximisation for the British crown. It even had certain administrative and military powers, allowing it to function partially as a state power. Until 1857, it administered several provinces of India. However, after India's First War of Independence in 1857, the British Crown dissolved the EIC, passed the Government of India Act in 1858, and controlled the administration of India through the appointment of a Viceroy (IGI-IV, 1909, p.16).

The primary motive of the EIC and British Crown was generating maximum revenue from India through maximum utilisation of India's natural resources. This motive led them to explore the possible ways of increasing the agricultural produce in India by intensifying irrigation. At first, they attempted to expand and maintain the TWI (discussed in Chapter 5). However, they failed to maintain TWI due to their lack of knowledge about the socio-cultural fabric in India. As Gilmartin (1994) points out, there was a conflict of interest between the British administrators and British Engineers. The administrators felt the necessity to understand the traditional systems, but the engineers influenced by modern science considered these systems inefficient and unproductive. They attempted to design modern dams and canals by applying the principles and theories of modern science and mathematics. For them, Imperial Science was far superior to the traditional water wisdom accumulated by people through several generations of close interaction with water. They failed to understand the importance of traditional beliefs, traditional knowledge, power relations and social order. The result as Worster (1985) describes was

"All mystery [of water] disappears from its depths; all gods depart, all contemplation of its flow ceases. It becomes so many 'acre-feet' banked in an account, so many 'kilowatt-hours' of generating capacity to be spent, so many bales of cotton or carloads of oranges to be traded around the globe" (Worster, 1985, p.52).

The traditional water infrastructure consisting of the localised tanks, lakes and ponds was unsuitable for the British to achieve their productive objective. Flexibility and negotiability in the sharing of water were the key aspects of these traditional water structures. They were scattered to such an extent that it was almost impossible for the British to bring them under their control. Therefore, the British searched for structures that would enable them to gain centralised control over India's water resources.

2.4.1. Dams and canals

Out of the various forms of TWI existing in India, the canals suited the British motive of gaining centralised bureaucratic control over water (Sengupta, 1993, p.10). Therefore, they chose to build several dams and lay a network of canals for irrigating vast tracts of land in India. In Pune, they commissioned labourers to build a dam at Khadakwasla in the 1870s and bring the water of the River Mutha by two canals – the Mutha Left Bank Canal and the Mutha Right Bank Canal (GBP-XVIII, Part II, 1885, p.15).

The dams and canals also proved useful for meeting the increasing water demand in Pune. Towards the end of the 19th century, Pune's population gradually started to increase as people began to settle near the Pune and Khadki Military Cantonments. The town also grew spatially, and the traditional systems could no longer serve the peripheral areas. Therefore, the British constructed additional dams, canals and laid a piped water supply system to serve the new upcoming areas of the town (discussed in Chapter 5).

To summarise, during the British Period, the ideas of comfort, luxury, science, and control play a critical role in shaping the water infrastructure. These ideas caused a discontinuity in the construction of TWI. The new modern infrastructure in the form of dams did have its advantage in increasing the rate of irrigation and also providing clean drinking water conveniently without the need to fetch it from public water structures. However, modern infrastructure lacked the potential to shape the urban form of Pune. Moreover, it affected the quality of agricultural land adversely because of increased salination and waterlogging (Whitcombe, 1995, p.237).

India became independent in 1947. After independence, the Indian Government could have encouraged the construction of TWI. However, due to changed urban realities and rapid population explosion, the Indian Government chose a quick and easy alternative of continuing the British Colonial trajectory of building large dams and more canals. These dams and canals represented new India traversing along the path of modernity and progress. The next section sheds light on the vision and ideas of the Indian Government about India's development, which manifested in the construction of several large dams and canals in independent India.

2.5. Water and modernity: Idea in Independent India

The large dams built by the British and especially large river valley projects such as the Tennessee Valley Project in the US had fascinated the western-educated Indian nationalists and engineers (Baghel, 2014, pp.10-11). Jawaharlal Nehru, the first Prime Minister of India who attained his higher education from Cambridge and London was mainly influenced by modern science and progress of Soviet Russia and Japan. Ambedkar, the architect of Indian Constitution, who completed his higher education from the US, was fascinated by the large infrastructure projects in the US. Both Nehru's and Ambedkar's ideas of progress and modernity shaped the water infrastructure of India immediately after independence.

Before independence, Ambedkar had worked as a member of the Labour Department in the Viceroy's Executive Council during 1942-1946 (Moon, 1991, p.220). His ideas about water management in India are reflected in some of his reports to the council and addresses in various conferences. In one of his speeches at a meeting held in the Indian city of Cuttack, Ambedkar expressed his ideas for controlling the flooding of rivers in the eastern state of Orissa. In his speech Ambedkar mentioned,

The United States of America had the same problem [of flooding] to face. Some of these rivers – Missouri, Miami and Tennessee – have given rise to the same problem in the U.S.A. Orissa must, therefore, adopt the method which the U.S.A. adopted in dealing with the problem of rivers. That method is to dam rivers at various points to conserve water permanently in reservoirs. There are many purposes which such reservoirs can serve besides irrigation. I am told that if it were possible to store the entire run off of the Mahanadi it will be enough to irrigate thereby a million acres, provided that much area was available. Water stored in the reservoirs can be used for generating electric power (Moon, 1991, p.305).

Consequently, to resolve the flooding of River Damodar in West Bengal and Bihar, the Damodar River Flood Enquiry Committee was appointed by the Government of Bengal in 1944 (Moon, 1991, p.220). Following Ambedkar's vision, the Committee came up with the proposal of damming the Damodar river valley in Orissa and Bihar. Similar to the Tennessee Valley Authority (TVA) that implemented the Tennessee Valley Project, a corporation called as the Damodar Valley Corporation (DVC) was constituted in India after independence in 1948 to execute the Damodar Valley Project (Baghel, 2014, p.10). A series of dams were built on the river in the 1950s. However, due to political neglect, the DVC did not gain the status of the TVA, nor did it capture the attention of people in India (ibid). Instead, three other projects inaugurated by Nehru after independence became the symbols of progressive modern India.

Independent India's First Five Year Plan (1951-1956) provided for three major river valley projects – Bhakra Nangal, Hirakud and Nagarjun Sagar in the north, east and south of India (Nehru Memorial Museum and Library, 2015). In the event organised for laying the foundation of the Nagarjun Sagar Dam, Nehru expressed his ideas about water and large dams. He said that for him laying the foundation of the dam was a sacred ceremony. Dams were the *new temples* being built all over India (Rao, 1979). Thus, for Nehru, dams were symbols of progressive modern India. Under Nehru's leadership, the first decade in India after independence witnessed the construction of 235 large dams in India (NRLD, 2017, p.2, abstract of large dams). Although a significant portion of public investments in agriculture was allocated in the creation of large dams, they failed to achieve the necessary outcome. Dam construction did not take into consideration the topography of the diverse regions in India. Dams were not viable, especially in the eastern floodplains and Deccan (Naz and Subramanian, 2010, Section 3.1).

Besides, large dams had severe ecological damages such as soil erosion and waterlogging. As these problems intensified in the late 1950s, Nehru realised the limitations of his vision. In 1957, he cautioned the chief ministers of various states to undertake an ecological survey of the proposed dam sites and examine the effect of dams on the flora and fauna of those sites and the wider region. In 1958, while addressing the Central Board of Irrigation and Power in New Delhi, Nehru said,

[..] we are suffering from what we may call 'disease of gigantism'. I want our engineers to undertake big schemes in the country, but the idea of having big undertakings and doing big tasks for the sake of showing that we can do big things is not a good outlook at all. [...] the small industries and the small plants for electric power, which will change the face of the country, far more than half a dozen big projects in a half dozen places (Nehru Memorial Museum and Library, 2015).

Irrespective of Nehru's changed outlook towards large river valley projects, the construction of large dams continued in India. In the 1960s, to boost the agricultural production, India introduced the use of high yielding and genetically modified seeds, intensive irrigation, chemical fertilisers and pesticides under the program of Green Revolution. The Green Revolution aimed at increasing the production of wheat especially in the states of Punjab, Haryana and Uttar Pradesh. Shiva (1991) has mentioned in detail the negative impacts of the Green Revolution. The Green Revolution and the utilisation of tubewell technology went hand in hand. In the 1970s, after the first decade of the Green Revolution, out of the total irrigated area in India, 17% was by tubewells. Within the next two decades, the area irrigated by tubewells rose to 32%. Irrigation by tubewells was most intensive in the three states under the Green Revolution Program. It was 75% in Punjab, 68% in Uttar Pradesh and 57% in Haryana. Although the Green Revolution increased the agricultural production in India and created a surplus for trade, it severely altered the traditional water use and affected the groundwater table in India. The environmental costs of Green Revolution were much more in comparison to its benefits. The hybrid seeds of Green Revolution were water-intensive. They required three times more irrigation than traditional varieties. Intensive irrigation destabilised the natural water cycle by adding more water to the ecosystem than its natural drainage potential. This excess water created waterlogging and increased the salinity of soil. At the same time, over-use of chemical fertilisers and pesticides polluted groundwater where groundwater table had already fallen due to over-dependency on tubewell technology. In short, use of inappropriate technology to create abundance created new water scarcity in nature through ecological destruction (Shiva, 1991, pp.121-145)

In addition to water being considered as an input for boosting the agricultural economy, it was also considered as a fundamental entity for the health and hygiene of cities and villages. Throughout every five-year plan, it has been the constant endeavour of the Indian Government to provide piped water supply to the cities and villages of India. The first five-year plan mentioned the vision to expand the piped-water supply network in India on lines of the expansion that occurred in U.K. and U.S.A. (Planning Commission, 1951). To fulfil the vision, water supply and sanitation program was set up in 1954 to carry out the expansion of water-supply network. Under the program, water-supply schemes were planned for some of the metropolitan cities such as Delhi, Calcutta, Madras, Bangalore, Ahmedabad, and Vishakhapatnam. During the period from 1951-74, the Government spent Rs 8550 million on provision of piped water supply. With this investment, 65% of the urban areas were covered by the piped water supply system.

This aspiration by the Indian Government to provide a uniform water supply network caused inequalities and social segregation. Water, which was an element that had the potential to unify people in ancient India, became responsible for dividing people. In cities such as Mumbai, the urban poor were left from the benefits of a water supply network (Gandy, 2008, p.114). Even at the national level, the allocation of funds for establishing a piped water network was always partial. The government focused on the water supply of big cities having population more than 100,000 and neglected the small cities. In comparison with the urban areas, the rural areas received less attention. Furthermore, the government saw water as an unlimited natural resource. Every time there was an increase in urban population, leading to the expansion of municipal limits, it attempted to extend the water supply network. However, the attempt of an extension could not keep pace with the rate of urbanisation, keeping the peripheral areas unserved by piped system. Thus, most of the urban areas display the 'weakness of India's aspirational modernity' (Gandy, 2008, p.116).

2.5.1. Conclusion

This chapter aimed to understand the conceptualisation of water in the ancient Hindu culture of India and the way it has shaped the TWI in Pune. Also, the chapter aimed to investigate the extent to which ideas and beliefs about water changed during the Deccan Sultanate, British-

Colonial and Post-Colonial periods. Based on the discussion so far, the following conclusions can be made:

Hindu Period: Ideas and beliefs about water being a sacred natural element

The ancient Hindu culture had deep reverence towards rivers, rainfall and different water bodies. This reverence emerged due to people's physical dependence on natural forms of water and recognising their value. The acts of personifying rivers as divine mothers and rainfall as the father of the sky represent people's total oneness with water. This feeling of oneness enabled people to accept both the creative and destructive properties of rivers and rainfall. The TWI built by the ancient Indians reflected their conceptualisation of water. The river diversion system and the construction of water storage structures such as podhis, taakya and baravs followed the principle of working with nature rather than attempting to overpower nature. Any alterations in the natural water bodies and landscape were mostly subtle and reversible.

Deccan Sultanate Period: Absorption of new technology without a change in ideas and beliefs

The ability of the Hindu culture to adapt to changing realities over time enabled it to absorb new technological innovations coming from Persia. The Persian technology was absorbed into the Hindu Culture. However, the adaptation of technology did not alter the core values of water present in Hindu Culture. As the core values remained unaltered, the use of new technology continued to be for the common good of the people. The technology of nahars brought in positive changes in Pune's landscape through the design of several gardens and water cisterns functioning as public places for recreation.

The British-Colonial and Post-Colonial Periods: Ideas about science, technology and modernity taking over core ideas

The principal motive of the British rulers in India was to gain productive control over India's natural resources. With this motive, they used modern science and technology for gaining centralised control over India's natural water sources and constructed large dams and canals in India. Continuing the British trajectory, foreign-educated and trained Indian nationalists and engineers intensified the construction of large-scale water infrastructure to display India's path towards progress and modernity. Moreover, the dynamic spatial and physical expansion of cities such as Pune also compelled them to opt for easy and quick solutions for providing clean drinking water.

To conclude, we find that the water infrastructure constructed during each of the periods discussed so far reflects the water-related ideas and concepts of that period. Table 2.1 presents the changing perception of water and the way it reflects in the water infrastructure built during the four periods.

Table 2.2: Changing perception of water and emerging water infrastructure and landscape.

Period	*Perception of water*	*Type of water structures/infrastructure*	*Landscape*
Hindu	Water as sacred, precious and limited	podhi, taakya, kund, barav, talav	Water structures as landmarks, visual reference points, part of a settlement
Deccan Sultanate	Flowing water as a landscape element	nahars	Orchards and gardens
British Colonial	Water for comfort and production	dams, canals, reservoirs	Away from the settlement, superimposed on settlement fabric
Post-Colonial	Water structures displaying modernity and progress	Large dams, tubewells	Invisible, laid as grid

Source: Author

The succeeding chapters discuss these different forms of water infrastructure. The next chapter examines how the conceptualisation of water as a sacred element in the ancient Hindu Culture is reflected in the river diversion system, podhis, taakya and baravs constructed from 1700 B.C. to 1400 A.D.

3. Sacred water: River diversion, podhis, taakya and barav

This chapter investigates four forms of Traditional Water Infrastructure (TWI): river diversion, podhis, taakya, and barav built from 17th century B.C. to 14th Century A.D. Besides, it also discusses three types of mechanisms: rahat, rahat gadge, and mot used for lifting water from the water storage structures. The chapter attempts to understand the key design principles that make TWI sustainable and multi-functional. The findings reveal that location-specificity, understanding of the geology and hydrology and architectural detailing are the characteristics of TWI that make them sustainable. In conclusion, the chapter discusses the way TWI transcends beyond its utilitarian function and attains religious and cultural significance.

3.1. Introduction

People's ideas and beliefs about water reflect through their TWI that diverts, captures and stores water. The concept of water being a sacred and life-nurturing element was embedded in the ancient Hindu culture of India, as seen in the previous chapter. Thus, this chapter aims to understand how this idea of sacredness influenced the design of four types of TWI: river diversion, podhis, taakya, and barav. An understanding of these four types of TWI is essential for two reasons: Firstly, apart from the river diversion system that does not physically exist, the other three types are the earliest surviving examples of TWI in Pune, more than eight hundred years old. Therefore, it becomes essential to understand their key design and construction principles that enabled them to withstand the test of time. Secondly, people imagined TWI to function not only as utilitarian structures but also as places for social gathering and interaction. Hence, a deeper understanding of TWI would shed light on the way TWI became multi-functional because of its architectural design and aesthetics. Therefore, this chapter seeks to explore the TWI by putting forth two main questions:

What were the key design and construction principles of TWI?

How did these principles assign a multi-functional character to the TWI?

This chapter explores various case examples of TWI built from the 17th century B.C. to the 14th century A.D for answering the two questions mentioned above. The timeframe under consideration is an extensive one spanning across more than three thousand years. The rationale for selecting such an extensive timeframe is that during its span, Pune was under the continuous rule of Hindu dynasties whereas other regions in India underwent several regime changes. Political stability favoured the flourishment of Hindu culture whose influence can be seen on the TWI designed during this timespan. Although the timespan is extensive, the case examples of TWI that have been selected belong to the following three specific periods:-

I. Deccan Chalcolithic Period[25] (17th to 8th century B.C.): River diversion system.
Ex: The river diversion system at Inamgaon.

II. Satvahana Period (2nd century B.C. to 2nd century A.D.): Podhis.
Ex: Podhis near Ganesh Caves, Junnar

III. Yadava Period (9th to 14th century A.D.): Taakya and Barav.
Ex: Ganga-Jamuna Taaki on Shivneri Fort, Junnar
Ex: Kamani Taaki on Shivneri Fort, Junnar
Ex: Barav at Loni Bhapkar, Baramati
Ex: Barav at Manchar, Ambegaon

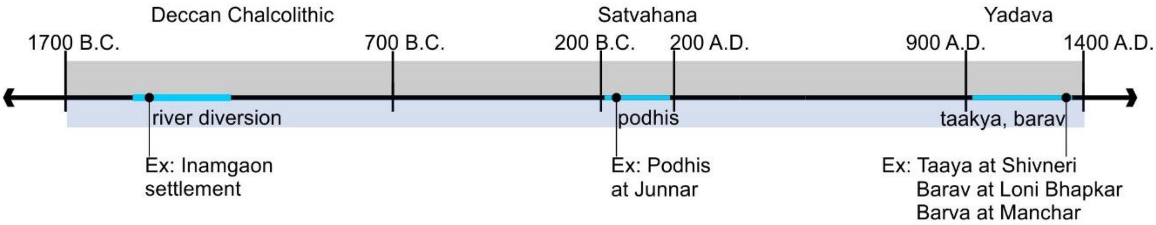


Figure 3.1: Timeframe with examples of water management from 1700 B.C. to 1400 A.D.
Source: Author.

The following section 3.1 discusses the act of river diversion during the Deccan Chalcolithic Period through the example of Inamgaon settlement along the banks of River Ghod in the Shirur Taluka of Pune. The case discusses how the first known settlers at Inamgaon tackled the issue of river flooding by diverting the flow of Ghod and storing its excess floodwater for the summer months.

Section 3.2 discusses two main types of rock-cut cisterns, namely podhi (a small rock-cut cistern) built during the Satvahana Period, and taaki (a large rock-cut cistern) built during the Yadava Period, found in the hill ranges of Junnar.

Section 3.3 discusses the development of several surface and groundwater harvesting structures such as kup (well), vapi (stepped-well), tadag (lake) and kund (stepped water tank) built during the Yadava Period. Out of these four types, examples of kunds with intermediate landings known as baravs can be seen explicitly in Pune and Maharashtra.

When t was possible for the people to physically access water, they would collect it in vessels and carry them over their heads. However, where the water was not easily accessible, people utilised various mechanical devices and techniques to lift water. Thus, Section 3.4 discusses the *rahat* (a type of pulley) and *rahat gadge* (pulley with a chain of small pots) as two popular

[25] Many village settlements dotted the landscape of Maharashtra in the second millennium B.C. These settlements were primarily located in the Tapi, Godavari and Krishna river valleys. Archaeologists and historians refer these settlements as collectively belonging to the 'Deccan Chalcolithic Culture' based on the remains of ceramic pottery found during this period (Schug, 2011, p.3).

devices for lifting water for household and irrigation purposes, respectively. Also, it discusses the *mot* (raising a leather bag with the help of animals such as bullocks and camels) as a technique used for irrigation purpose. Lastly, the chapter summarises the key sacred and artistic features of the water storage structures and emphasises on their aesthetic and multi-functional character.

3.2. River diversion during the Deccan Chalcolithic Period (1700 -800 B.C.)

3.2.1. Background

During the 17th – 8th century B.C., a part of the Deccan Chalcolithic Period, various small village settlements came up in the Deccan plateau region of Maharashtra (Sankalia et al., 1971,p.139). They were small farming communities whose sources of livelihood were agriculture, stock raising, hunting, and fishing. The settlers considered flood plains near river bends as favourable sites for locating their settlements. As flood plains retained some quantity of water even in summer when the river itself or its nearby areas went dry, they could be utilised by the farmers for fulfilling their basic water requirement. Many such settlements existed near major rivers of Pune such as Bhima, Mula, Mutha, Vel, Karha and Ghod (Naik and Mishra, 1997, p.47).

Out of these settlements, the one along the western bank of the river Ghod at Inamgaon in the Shirur taluka of Pune is of particular importance for its ancient river diversion system. Archaeological remains of the settlement indicate that it is nearly four-thousand-year-old. It spanned across three cultural periods —Period I: Malwa Culture (1700-1400 B.C.), Period II: Early Jorwe Culture (1400-1100 B.C.) and Period III: Late Jorwe Culture (1100-800 B.C.) (Sankalia et al., 1971, pp.140-142). Out of these three cultural periods, the Early Jorwe Period was the most prosperous period due to the occurrence of good rainfall and the availability of ample water from the River Ghod.

The seeds recovered from the excavations suggest that the villagers cultivated a variety of crops like sorghum, barley, horse gram, hyacinth bean, lentil, and pea (Dhavalikar, 2006, p.9). Amongst them, barley was the most extensively cultivated crop. Since it is a drought-resistant crop; the farmers of Inamgaon could grow it even when the rainfall was scarce. Therefore, archaeologists found a large number of barley seeds belonging to all the three cultural periods in their excavation (ibid). However, what was surprising for the archaeologists was the presence of wheat belonging to the Early Jorwe Period. They did not find traces of wheat belonging to the Malwa and Late Jorwe cultures. Furthermore, they did not find wheat at any of the other archaeological sites belonging to the same period. As wheat is traditionally a winter crop, its cultivation is only possible when there is an availability of water which would not have been possible in a drought-prone region such as Inamgaon. Consequently, the archaeologists assumed that either the Inamgaon farmers imported wheat from other places, or they had developed some irrigation technique (Khaladkar, 2018, p.8). Their assumption about the possibility of having an irrigation system proved correct when they studied the settlement pattern in detail and found the remains of a canal and an embankment wall (Sankalia et al., 1975, p.6).

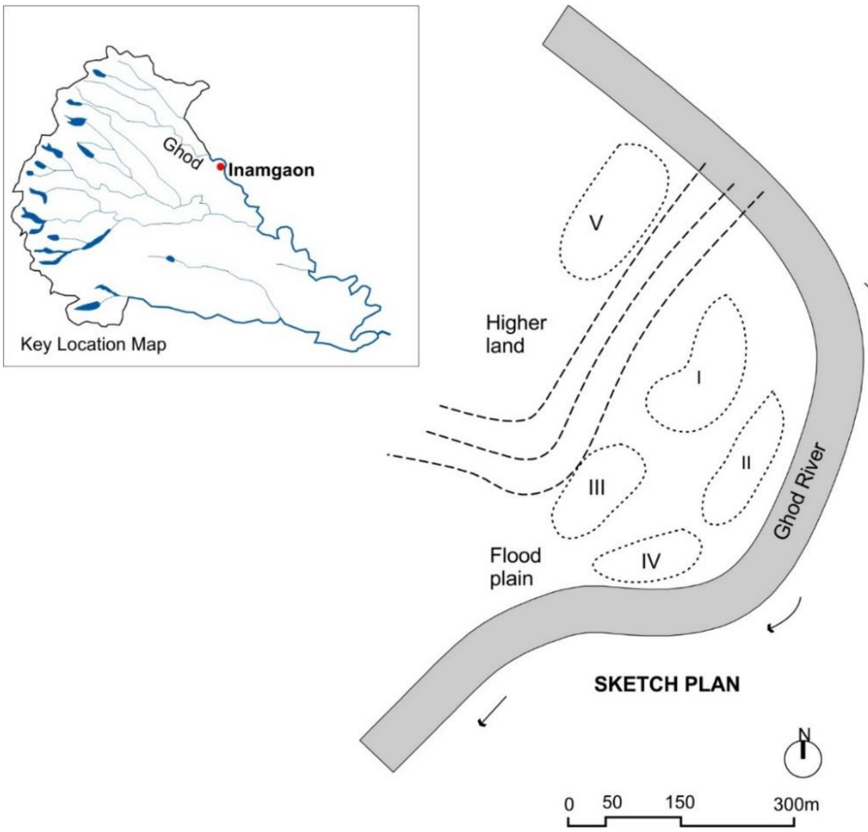


Figure 3.2: Sketch map showing the archaeological site of Inamgaon.
Source: After Dhavalikar, 2006, p.11.

3.2.2. Inamgaon settlement and diversion of Ghod River

The settlement of Inamgaon was spread over an area of 65 acres (Sankalia et al., 1971, p.140). The Ghod River flows from north to south, with an eastward turn at its upstream and a westward turn at its downstream, forming a crescent-like region of the flood plains to its west (Ref Fig 3.2.). The settlements were located on five different elevated terrains in this floodplain commonly denoted by archaeologists with numbers I to V. While the settlements I to IV were located close to the river, settlement V was located slightly away from the river on a high land towards the west of the river. During the Early Jorwe period, Ghod River was probably prone to flooding in the monsoons, affecting the settlements located in its floodplain. To overcome the challenge of flooding, the farmers devised a strategy to protect their settlements and at the same time utilise the river flooding for the benefit of their agriculture (Dhavalikar, 2006, p.10). They diverted the excess water from the Ghod River by constructing a canal that was about 420m long, about 6m wide and 4m deep at its centre. It resembled a trench that was cut up to the hard rock surface. Archaeologists believe that the canal would divert about 54,000 cu.m of water (Khaladkar, 2018, p.9). The farmers utilised the diverted water for irrigation. Thus, the canal made their settlements less vulnerable to flooding. Additionally, the farmers also built a

240m long and 3m wide stone rubble wall next to the canal, running along the western edge of settlement V. It functioned as a type of flood protection embankment for the canal. The construction of the canal helped the farmers to flourish and prosper (ibid). From the archaeological remains, archaeologists believe that the farmers constructed a jetty in the northeastern corner of their settlement. Adequate water in the river enabled them to ply small boats over it (Sankalia et al., 1975, p.6).

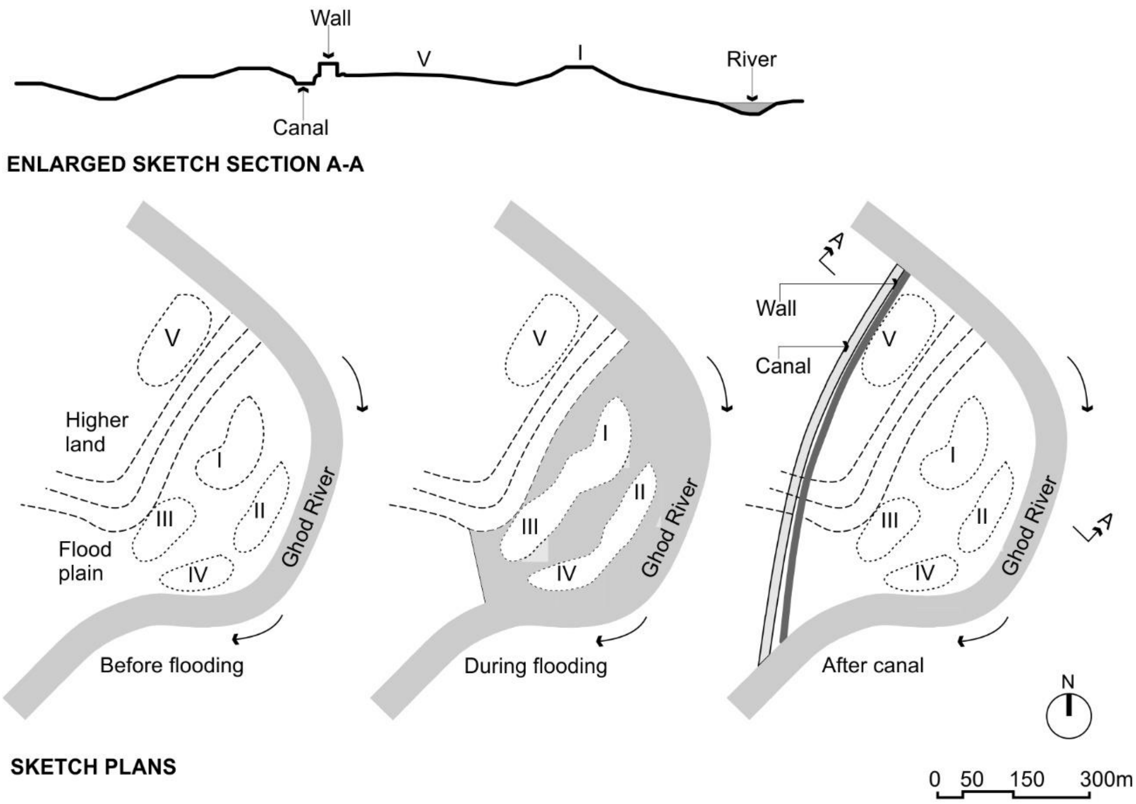


Figure 3.3: Sketch plans and section indicating the provision for flood protection at Inamgaon. Source: Adapted from Dhavalikar et al., 1988; Dhavalikar, 2006, p.11.

However, the favourable climatic conditions during the Early Jorwe period underwent a significant change during the Late Jorwe period (Schug, 2011, p.57). The rainfall decreased, and the Ghod river became drier than before. It became difficult for the farmers to depend entirely on agriculture for their subsistence. As a result, they shifted to other activities like hunting and cattle rearing. Their diversity in subsistence enabled them to persist for 300 years longer in comparison to their other contemporary settlements elsewhere (Schug, 2011, p.59). However, towards the end of the Late Jorwe period, the farmers resorted to the cultivation of water demanding crops instead of the traditional cultivation of drought-resistant barley crop assuming that the River Ghod would fetch enough water for their cultivation. However, this change in crop pattern proved unsustainable against the backdrop of changing climatic conditions. The Ghod became drier than before and could not provide the required quantity of water for growing the water-rich crops. Therefore, in search of alternative water sources and better livelihood, the farmers of Inamgaon abandoned their village and migrated to other suitable locations around 800 B.C.

3.2.3. Concluding summary

The Inamgaon settlement presents the case of one of the earliest modifications of the natural landscape in Pune. Nevertheless, this modification is far different from the current post-industrial river modifications. Humans and other species have always altered the natural landscape in some or the other way. However, most (not all) of the pre-industrial alterations of rivers were reversible. On the contrary, in the post-industrial era, human action has transformed rivers, effected their natural flow and caused irreversible damages (Baghel, 2014, p.2). Moreover, unlike the post-industrial transformations of rivers, very few of the pre-industrial alterations, especially in Asia attempt to overpower nature.[26] Instead, these alterations attempted to work with nature in a sustainable manner (Paranjpye and Paranjpye, 2005, p.336)

Gradually, with the advancement in irrigation and water harvesting techniques, it became possible for ancient people to have their settlements away from rivers. Their dependence on the river for agriculture reduced to a certain extent. As settlements moved away from the river, people constructed several water storage structures that stored groundwater and rainwater, ensuring reliable year-round water supply. The next section discusses rainwater storage structures known as podhis constructed by the Buddhist Monks during the Satvahana Period.

3.3. Podhis storing rainwater during the Satvahana Period (200 B.C.-200 A.D.)

3.3.1. Introduction

Podhis were small water cisterns built commonly by artisans for the Buddhist and Jain monks who stayed in the rock-cut dwellings on top of hills. Cave-dwellings were monsoon retreats for monks who stayed there for doing meditation as well as for training their disciples (Murayi, 2016, p.131). These cave dwellings were of two types: Chaityas and Viharas. Chaityas were halls for prayer and meditation, while viharas were residences in the form of rock-cut cells. Many such chaityas and viharas are found in the hills ranges of Maharashtra. Ajanta, Ellora, Nashik, Karle, Bhaja, Kanheri, Junnar are some well-known places in Maharashtra having chaityas and viharas (Fergusson and Burgess, 1880, p.iv). Almost all chaityas and viharas were located along primary trade routes in Deccan. Therefore, many merchants and traders who passed along these trade routes patronised the construction of chaityas, viharas and podhis. Besides them, royal personnel, officers, and sometimes even masons, gardeners and monks

[26] Not all pre-industrial societies designed their water management systems in a sustainable manner. For instance, excessive irrigation by the Sumerians led to problems of waterlogging and salinity in the soil. Similarly, the Romans also attempted to control rivers through the aqueduct technology. However many pre-industrial societies such as Egyptian, Mesopotamian and Indus Valley attempted to work with nature rather than overpowering it (Paranjpye and Paranjpye, 2005, p.335).

were the patrons for constructing these structures (Alone, 2002, p.111). These patrons gave donations to the different groups of Buddhist monks known as *sangha*. From these donations, the Sangh hired artisans who carved the chaityas, viharas and podhis (ibid).

In the beginning, the monks stayed in these cave-dwellings only during the monsoon and for the remaining period, they travelled through different villages to spread the teachings of Buddhism and Jainism (Pandit, 2018, p.90). Consequently, during the monsoon, rainwater could be directly stored in vessels, and there was no need to have permanent storage of water. Gradually, as the monks settled permanently inside the viharas, they constructed several podhis for fulfiling their year-round water requirement. Primarily, podhis were of two types: those that stored rainwater and those that stored groundwater and had springs inside them (Murayi, 2016, p.134).

Their methods of construction were slightly different. The monks constructed small rectangular or square podhis just at the mouth of the chaityas and viharas for storing the rainwater flowing down the hill slopes. At the same time, rainwater falling on the hard basaltic strata seeped inside it through the cracks and fissures in the pervious layers. Finally, it accumulated in the impervious layer of the strata in the form of groundwater. The monks cut deeper podhis up to the junction of the pervious and impervious layers for accessing this groundwater (Pandit, 2018, p.91). The podhis were mainly of two types based upon the use:— those that stored water for drinking purpose and those that stored water for bathing purpose. The later ones had steps on any one of their sides to access the water. Additionally, water from the podhis was also used for carrying out rituals (ibid). Stone inscriptions mention various types of podhis.[27] Many such podhis are still functional until today and are found at various places mentioned before.

Within Pune, the Junnar Taluka contains about 135 rock-cut caves (GBP-XVIII, Part-III, 1885, p.163). These caves are spread across five hill ranges around Junnar. Many of these caves have podhis for storing groundwater and rainwater. Few of the podhis that are a part of the Ganesh Caves located to the north of Junnar town were studied as part of this research.

3.3.2. Examples: Podhis near Ganesh Caves

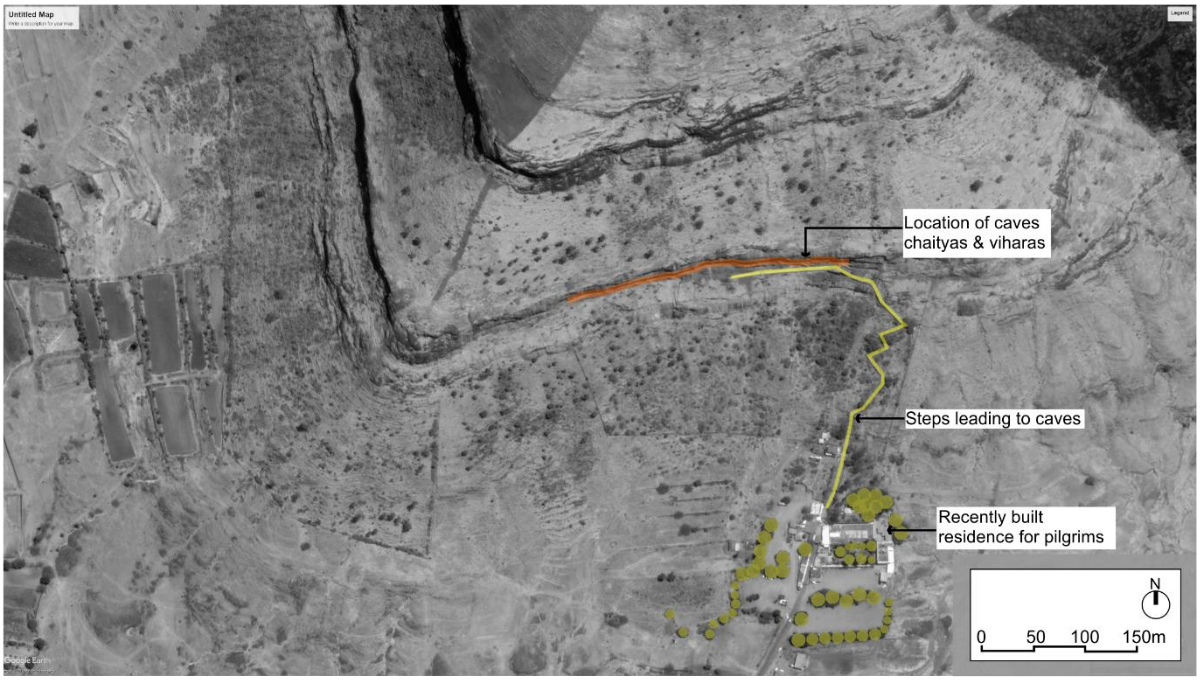
The Ganesh caves consist of two chaitya halls and 38 viharas built from the 1st to 3rd century A.D. (ASI, 2008). Similar to the caves found elsewhere in Maharashtra, the Ganesh caves are located near the trade route that connected Pune to the Konkan Region of Western Maharashtra. Therefore, traders and artisans patronised the construction of these caves. Few of the podhis located in front of the chaityas and viharas have stone inscriptions mentioning

[27] It seems that podhis were of different types such as Paaniyapodhi, Paaniyak, Paniyak Bhajanam, Nhanpodhi, etc. Paaniyapodhis were the ones that stored drinking water and Nhanpodhis were the ones that stored bathing water. This indicates that based on the use, there could have been slight alterations in the design of podhis. For instance, the podhis for bathing had steps (Pandit 2018, p.90).

the name of the donor who supported their construction. For instance, in between caves XVII and XVIII, there are three podhis. Two of them have inscriptions mentioning the name of the donors. The first inscription states,
'the podhi is a meritorious gift by a goldsmith named Sanghaka, son of Kudira of Kalyan' (GBP-XVIII, Part-III, 1885, p.214).

The second inscription states,
'the podhi is a meritorious gift by Lachhinika, wife of Torika the Nadaka and Nadabalika, wife of Isimulassami' (GBP-XVIII, Part-III, 1885, p.214).

(a) View of the Ganesh caves



(b) Location of the Ganesh caves

Figure 3.4: The Ganesh Caves at Junnar
Source: (a) Photograph taken by the author during field research carried on 29-11-2018.
(b) Google Earth Pro 7.3.2.5491, 05-01-2018a. Lenyadri Ganesh Caves.

Both the inscriptions indicate that the wealthy class of traders and artisans, including rich women, patronised the construction of podhis for meeting the water requirements of the monks, ordinary people and travellers who passed by the trade route. Patronising the construction of podhis was considered as an act of religious merit in the Buddhist society[28], which encouraged the wealthy class to support this cause willingly.

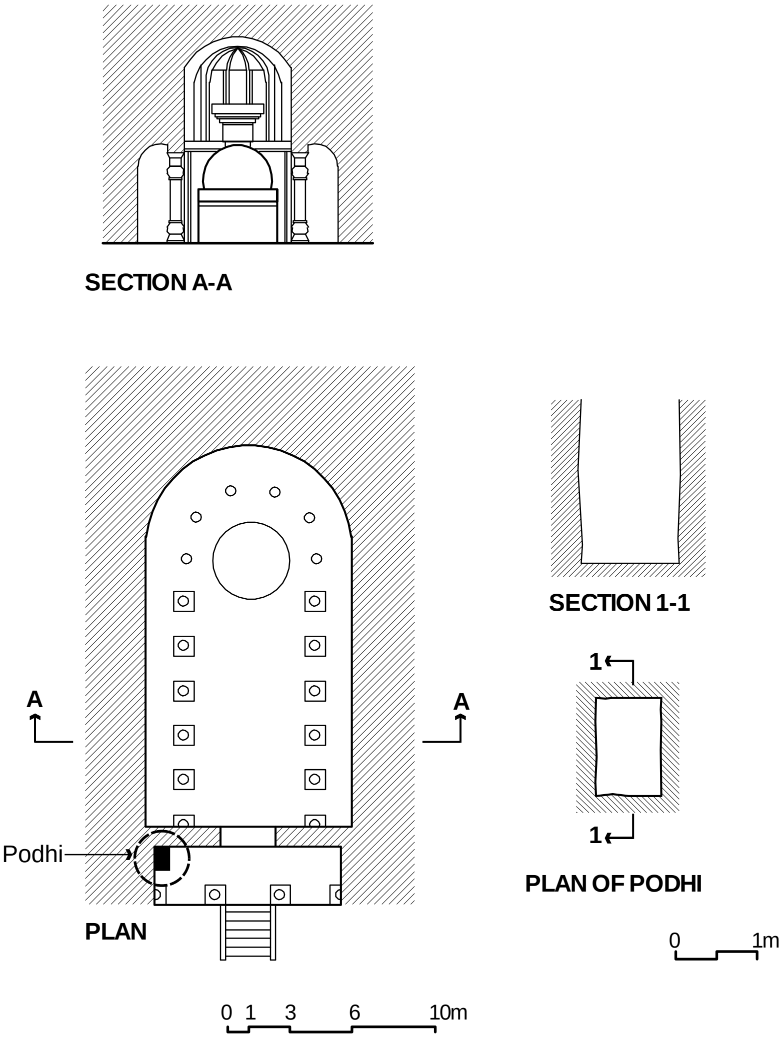


Figure 3.5: Plans and sections of a chaitya hall and podhi
Source: Fergusson and Burgess, 1880, Plate XVIII.

Many of the podhis in front of caves are currently difficult to access due to slippery terrain. Nonetheless, the one observed during the field research measured 1.2m x0.8m. The podhis have little storage capacity. Usually, every cave had its podhi, and only the monks who stayed inside the particular cave used its water.

The podhis were no more than simple water storage structures. They did not have any elaborate design. Nonetheless, they are good examples of carrying slight alterations in the hilly terrain

[28] The Satvahanas patronised both Hinduism and Buddhism. Since, Buddhism was an offshoot of Hinduism, the idea of meritorious gifting of water structures for public good existed even in Buddhism (Pandit, 2018, p.91).

for storing water. The strategic location of podhis is also an indication of the traditional knowledge of geology and hydraulics prevalent in ancient society.

More elaborate forms of podhis known as taakya and groundwater storage structures known as baravs evolved during the period of the Yadava rulers. The following section discusses the salient features of these structures.

3.4. Taakya and baravs during the Yadava Period (900-1400 A.D.)

3.4.1. Taakya: Introduction

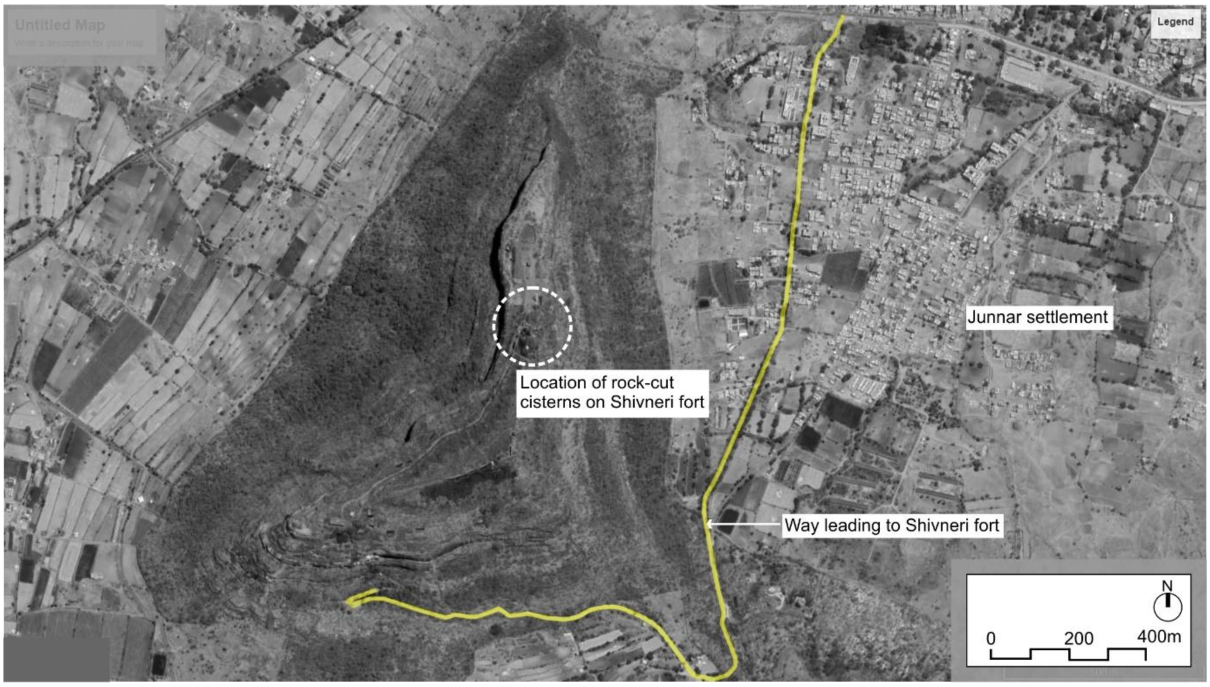


Figure 3.6: Sketch map of Shivneri fort, Junnar showing the location of taake.
Source: Google Earth Pro 7.3.2.5491, 05-01-2018b. Shivneri Fort, Junnar.

After the 3rd century A.D., elaborate rock-cut cisterns known as taakya are seen during the time of Devgiri Yadavas (1170-1318 A.D.) Such taakya can be found on the Shivneri fort in Junnar. The fort is located towards the west of Junnar and rises about 300 metres above ground level (GBP-XVIII, Part-III, 1885, p.153). It is somewhat triangular, as shown in Figure 3.6. Similar to the Ganesh caves discussed in the previous section, the Junnar Fort also has remains of some Buddhist caves and podhis. Most of them are located on its eastern side. The taakya on the fort stand out distinctly from the podhis due to their style of construction and architecture. The same principle used for constructing podhis was followed in the creation of a taaki. The rock was cut up to the junction of pervious and impervious layers (Ghanekar, 2006, pp.15-16). However, they were cut horizontally inside the rock bed like caves. A small portion enough for fetching water was kept open to the sky. The remaining portion was within the rock bed. The rock surface above it was supported on columns carved out of the same rock. Since the water was least exposed to the outside environment, its rate of evaporation was negligible. Moreover, it also remained cool inside (ibid). Their construction features are explained in detail with the help of the following two examples.

3.4.2. Case example: Ganga-Jamuna Taakya on Shivneri fort, Junnar

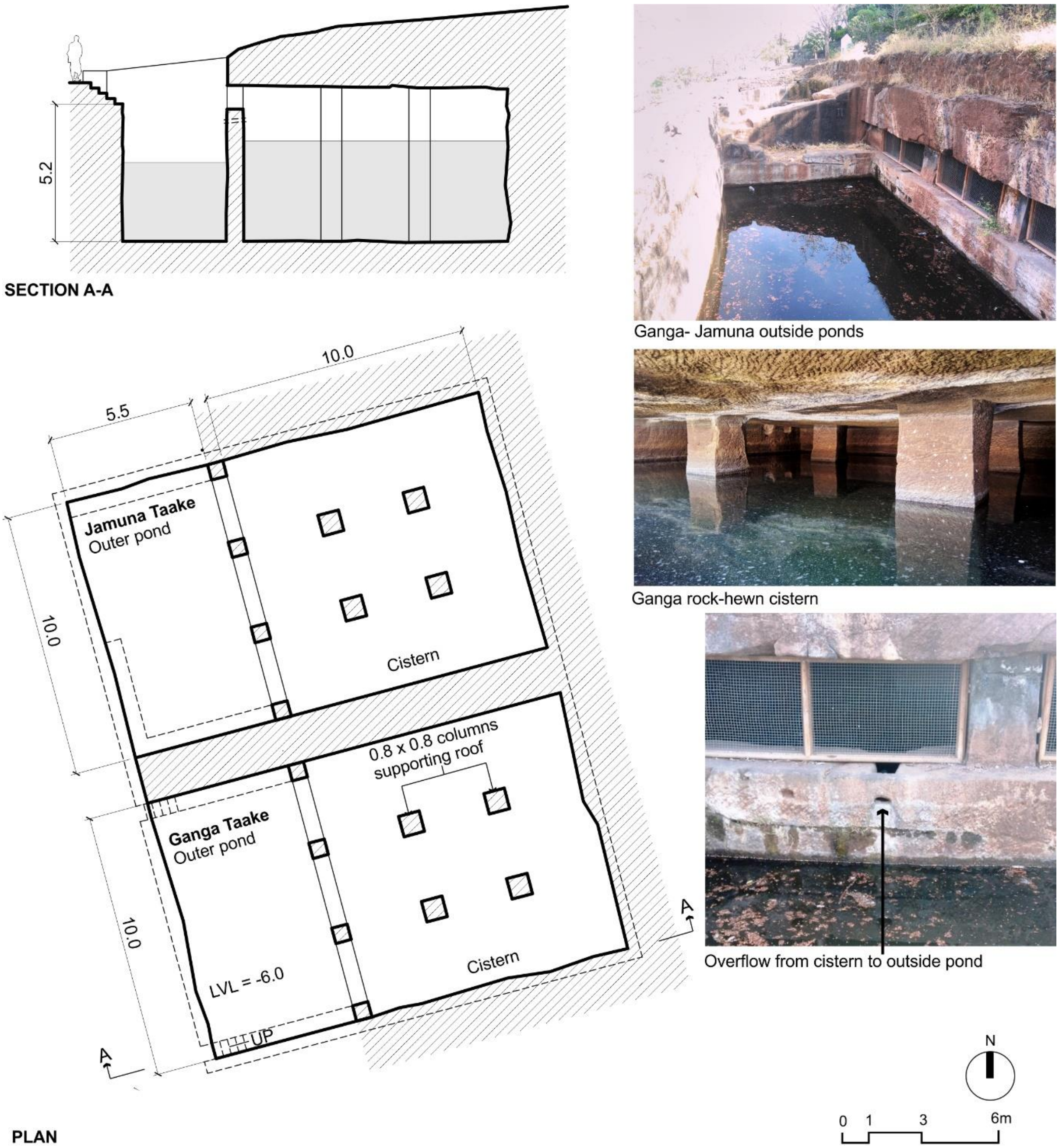


Figure 3.7: Plan, section and photographs of Ganga-Jamuna taake on Shivneri, Junnar.
Source: Author. Field Research carried on 29-11-2018.

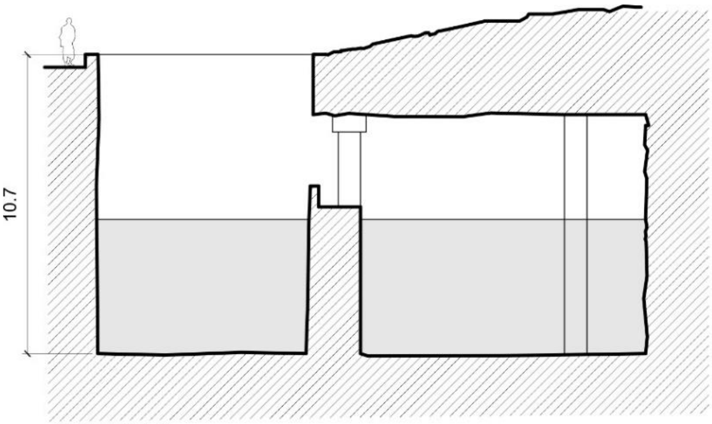
The Ganga-Jamuna taakya together form a pair, each having an outer pond of size 10m x 5.5m. Behind the pond, both support a cistern that is hewn 10m under the hills (See figure 3.7). Eight square pillars about 0.8 m x 0.8 m in size and about 5m high support the roof (GBP-XVIII, Part-III, 1885, p.163). The outer pond and the cistern behind the pond seem to have a depth of about 5m. A parapet wall separates the outside pond from the inside cistern. In between the parapet wall, three square pillars with capitals support the roof. Excess water from the rock-hewn cisterns overflows into the outside pond. Besides the overflowing water, rainwater also gets collected in the pond. Probably, a small drainage outlet in the pond, below the level of the inlet drains out the excess water from it and prevents the back entry of water into the cistern again. The field observation suggests that the drainage outlet is located inside the pond roughly below the adjacent ground level. A 0.6m landing is constructed slightly above the outlet for people to fetch water.

A parapet wall with a very narrow entrance provides access to the taakya. It is safe to assume the water stored in the rock-hewn cistern was used for drinking purpose since it was least exposed to the outside environment and the water from the pond for washing clothes and utensils. A very rough calculation based on the dimensions of the taakya suggests that the two ponds outside the taakya would together store about 550m^3 (0.55 million litres) of water while the rock-hewn cisterns would together store about 1000 m^3 (1 million litres) of water. Both these figures are a rough estimate, and a detailed geological and hydrological analysis of the taakya is required to cross-verify and determine the precise storage capacity.

3.4.3. Case example: Kamani Taaki on Shivneri fort, Junnar

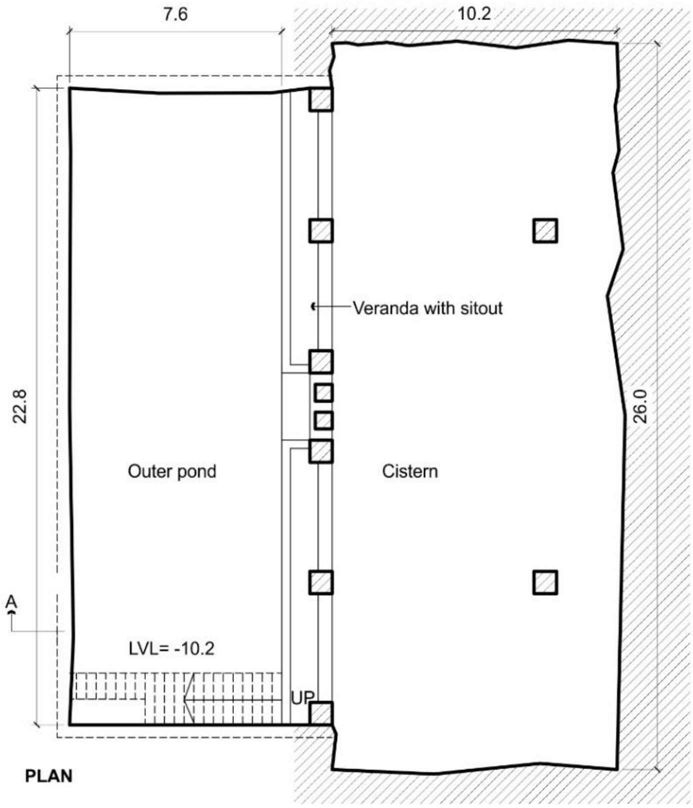
The design of Kamani taaki is similar to the design of the Ganga-Jamuna Taakya. The only difference is that the Kamani Taaki is larger as compared to the Ganga-Jamuna taaki. The outside pond is about 23m long, 7.5m wide and 6m deep. The rock-hewn cistern is about 26m long, 12m wide and 5m deep (GBP-XVIII, Part-III, 1885, pp.162-163). A landing is present within the outside pond about 4.5 m below the adjacent ground level that can be reached by climbing down a straight flight of steps.

A significant feature of this water cistern is the presence of a veranda in between the outside pond and inside the cistern. It also has a seating arrangement. Four central square pillars with faces about 0.8m wide and height about 1m and two side pillars with the same dimensions support the roof above. Besides these six pillars, two pillars in line with the side pillars present behind them within the cistern provide additional support to the roof above (ibid). Unlike the Ganga-Jamuna cisterns, the drainage arrangement of the Kamani cistern is invisible due to the difficulty in accessing it. Based on the dimensions of the taaki, one can make a very rough estimate of its storage capacity. The outside pond could store about 1035 m^3 (1 million litres) of water, while the rock-hewn cistern could store about 1560 m^3 (1.5 million litres) of water. However, these values are not accurate, and a detailed geological and hydrological analysis would be required to cross-verify and calculate the capacity of the taaki precisely.



SECTION A-A

Outside pond



PLAN

Veranda with sitout behind the pond

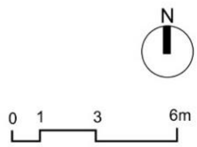


Figure 3.8: Plan, section and photographs of Kamani taaki on Shivneri fort, Junnar.
Source: Author. Field Research carried on 29-11-2018.

Similar to the podhis described in the previous section, taakya are also primarily utilitarian structures. The primary difference that can be seen between the two is that taakya are structurally more innovative and elaborate in comparison to the podhis. Taakya also reflect a gradual shift in the design of water infrastructure in the sense that it starts gaining a visual form, starts becoming more artistic and elaborate. To exemplify, the Kamani Taake has dressed columns with a base and a capital, and a verandah. However, the taakya are still devoid of any religious inscriptions, sculptures or ornamentation. Furthermore, both the podhis and taakya are somewhat standalone structures. Since they are not part of a settlement directly, it is difficult to establish a spatial relationship between settlement design and water infrastructure.

The relationship between water infrastructure and surrounding structures starts to build up slowly with the construction of baravs. The next section discusses this relationship and the principles behind the construction of baravs as rainwater and groundwater storage structures.

3.5. Barav (900 – 1400 A.D.)

3.5.1. Introduction

Baravs are stepped square or oblong rain and groundwater storage structures (Pathak, 2018, p.77). They are subterranean structures, and in the section, they resemble a funnel[29] (Hegewald, 2002, p.121). They have one or more intermediate landings for standing and fetching water. Most of the baravs have a square shape, some are rectangular, while a very few are octagonal.[30] Their size decreases from top to bottom. They have a parapet wall around them with one or more entrances. The name barav is believed to have originated from its unit of measuring the length called *'bav'*. One bav is equivalent to 1.5m; *bara,* i.e. twelve such bavs make up one barav. Therefore, some of the baravs are square in plan with its side approximately measuring 18m (12x1.5=18). However, this is not a fixed rule. Several baravs have their sides shorter or longer than 18m.

<u>Placement of baravs with respect to settlement</u>

The period from the 9th - 14th centuries was the peak period of barav construction (Pathak, 2017, p.21). From this period onwards, one can observe the gradual emergence of certain principles for situating the barav with respect to the settlement. Baravs were usually located near the entrance or boundary of a settlement, village, or a town. A tree with a sit-out around it and a barav next to it was a common sight in most villages (Maharashtra State Gazetteer, 1968, p.138). Many times settlements came up around the barav. Such baravs often fulfilled the water requirement of an entire settlement or a village. Certain ancient texts like the Brihatsanhita by Varahamihir (500 A.D.) mention certain principles for locating barav. The chapter on the exploration of water springs has many guidelines for choosing an appropriate site for locating a barav. Few of the guidelines are as follows:

The orientation of the barav should be such that its longer side is not along the north-south sides but along the east-west sides to protect it from rain and strong winds (Sastri and Bhat, 1946, pp.481-482)[31].

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[29] Baravs are popularly also called as kunds. However, kunds usually do not have any intermediate landings while baravs have one or more intermediate landings.

[30] There seems to be no rule for determining the shape of a barav. However, the ancient text Aparajitapriccha by Bhuvandev (1175-1250) mentions Bhadraka, Subhadraka, Nanda and Parigha as four types of kunds in front of temples, all of them having four arms and corners. Subhadraka should have porches in addition, while Parigha should have a dividing wall (Mate, 1998, pp.21-22).

[31] The original Sanskrit verses are:
पाली प्रागपरायताम्बु सुचिरं धत्ते न याम्योत्तरा
कल्लोलैरवदारमेति मरुता सा प्रायशः प्रेरितैः

It also mentions that preferably trees such as banyan (Ficus benghalensis), peepal (Ficus religiosa), mango (Mangifera indica), and neem (Azadirachta indica) should be planted near the barav not only to keep the barav under shade, but also to retain the moisture in the soil (Sastri and Bhat, 1946, p.482)[32]*.*

There is usually sweet water at places that have a cover of Munja grass, reeds, and where the earth is black or red, mixed with pebbles (Sastri and Bhat, 1946, p.478)[33]*.*

Thus, based on such guidelines, experts constructed a barav after inspecting the colour, texture, smell, touch, vegetation and the water holding capacity of the site. The guidelines also show that the ancient people had their traditional knowledge of geology and hydrology for constructing water structures. Most of the baravs in the state of Maharashtra seem to have been designed based on similar guidelines. Almost all the baravs found in Maharashtra have an average depth of 7m, and they generally do not exceed a depth of 11m. This depth was considered appropriate for accessing good quality of groundwater (Pathak, 2017, p.32).

Apart from having a utilitarian function, baravs also had a strong religious significance. Most of the temple complexes had baravs that functioned as bathing structures since taking a bath before entering the temple was one of the important religious rituals. Such temple complexes were located either within the settlement or outside the settlement depending upon the deity housed in the temple. For instance, ancient texts on architecture such as *Vaikhanasagama, Samarangan Sutradhar* and *Vastushastra*[34] state that temple of Lord Shiva should be located towards the northeast, while that of Lord Vishnu should be located towards the west (Kramrisch, 1946, pp.233-235). Similarly, Gods having wrathful expression should face away from the habitation, while Gods having peaceful expression should face towards the habitation. However, some of the temples do not follow these rules strictly. These rules are explained later through the example of the Shiva Temple at Loni Bhapkar.

In addition to their religious importance, temples were also a daily meeting place for the people, a place for social interaction, and a place of rest for the pilgrims (Pathak, 2017,p.22). As a result, even baravs became multifunctional and important landmarks within the settlements. They were places for social interaction in the presence of water. They played an important role in marking boundaries within the settlement such as public and private, and sacred and profane (Jain-Neubauer, 2016, p.9) as illustrated in the case examples later.

तां चेदिच्छति सारदारुभिरपां सम्पातमावारयेत्
पाषाणादिभिरेव वा प्रतिचये क्षुण्णं द्विपाश्वादिभिः (Brihat Samhita Adh.LIV.Sl.118).

[32] कुकुभवटाम्रप्लक्षकदम्बैः सनिचुलजम्बूवेतसनीपैः
कुरबकतालाशोकमधूकैर्बकुलविमिश्रैश्वावृततीराम् (Brihat Samhita Adh.LIV.Sl.119).

[33] या मौजिकैः काशकुशैश्च युक्ता नीला च मृद्यत्र सशर्करा च
तस्यां प्रभूतं सुरसं च तोयं कृष्णाथवा यत्र च रक्तमृदा (Brihat Samhita Adh.LIV.Sl.103).

[34] These ancient texts are part of shilpa shastras, i.e. texts mentioning the principles that one has to follow while constructing temples and settlements or designing the town.

Construction features

Based on the way of storing water, baravs are of two types: baravs storing water by taping the underground springs and baravs storing water by diverting it from a nearby water body (Mate, 1998, p.105). The examples of the second type are extremely rare. Almost all the baravs receive water through an underground spring. Besides, they also store rainwater. However, some baravs have the arrangement to discharge excess water (as explained in the case of barav at Manchar).

In the construction of a barav, there was a need to take special care of the forces acting on the steps of the barav – the soil pressure from the external side, hydraulic pressure from the internal side and the self-weight of the steps (Pathak, 2017, p.33). Proper care was taken to ensure that the resultant of the forces acting on the foundation of the steps and the retaining wall passes through its middle-third portion for preventing the occurrence of any tension. In many cases, additional stones are set within the steps to provide additional anchorage. These stones served as extensions of steps and functioned as seating platforms. Adjacent steps were joined either using a tongue and groove joint or by pouring molten lead in between their groves to hold them together.

Kings, noblemen, rich people, and village heads undertook the financial responsibility of constructing a barav, while the villagers undertook its construction and maintenance. Certain baravs such as the one at Manchar discussed later contain stone tablets specifying the name of the person who provided the necessary financial support for constructing the barav.

Artistic features

Certain baravs had a pillared pavilion called as mandap built along one or more of their sides (as seen in the case of barav at Loni Bhapkar). A portion of the mandap protruded into the stepped section of the barav (Hegewald, 2002, pp.129). The purpose of this mandap was two-fold. Firstly, it served as a kind of pavilion for fetching water. Secondly, it acted as a covered sit-out next to water. The mandap sometimes housed a deity inside. This deity was generally an incarnation of the main deity. For instance, the mandap at Loni Bhapkar contained the statue of a *Varaha* (boar) who is an incarnation of Lord Vishnu.[35] The sides of the mandap were richly ornamented with decorative motifs and mythological figures from *Puranas* (Dandawate et al., 2006, p.4). In some cases, a barav had more than one mandap along its sides.

The parapet wall of the barav played a vital role in giving it the sense of a sacred place. The internal sides of the parapet wall had niches known as *devkoshtas* that housed different deities. The number of niches and the deities within them varied from barav to barav. There seem to

[35] The Puranas mention ten incarnation of Vishnu popularly known as Dashavtar. The incarnation of boar is the third incarnation. The incarnations symbolise the evolution of life from first incarnation of fish to the tenth incarnation of a human being (Vijaydhwaja, ed. by Balsubramanian, 2016).

be two reasons for placing the deities in the niches of baravs. Firstly, people believed that these deities ward off evil powers emerging from the water (Hegewald, p.128). Secondly, the presence of deities encouraged people to maintain the sanctity of the place. It constantly reminded the people about the value of water and the need to use it cautiously without polluting it.

Even the series of steps starting from the parapet wall and leading up to the stored water had multiple functions. In addition to their primary function of providing access to water, depending upon the number of steps immersed in water, people understood the quantity of water available for their use and could adjust their consumption accordingly. At different times of the day, these steps cast beautiful shadows. The steps would then enable people to sit in the shade, interact with one another and also enjoy the presence of water. This multifunctionality highlights how baravs transcended their intended use of water harvesting and storage and created a socio-cultural and socio-technical identity. The following section discusses the case example of the barav at Loni Bhapkar.

3.5.2. Case example: Barav at Loni Bhapkar

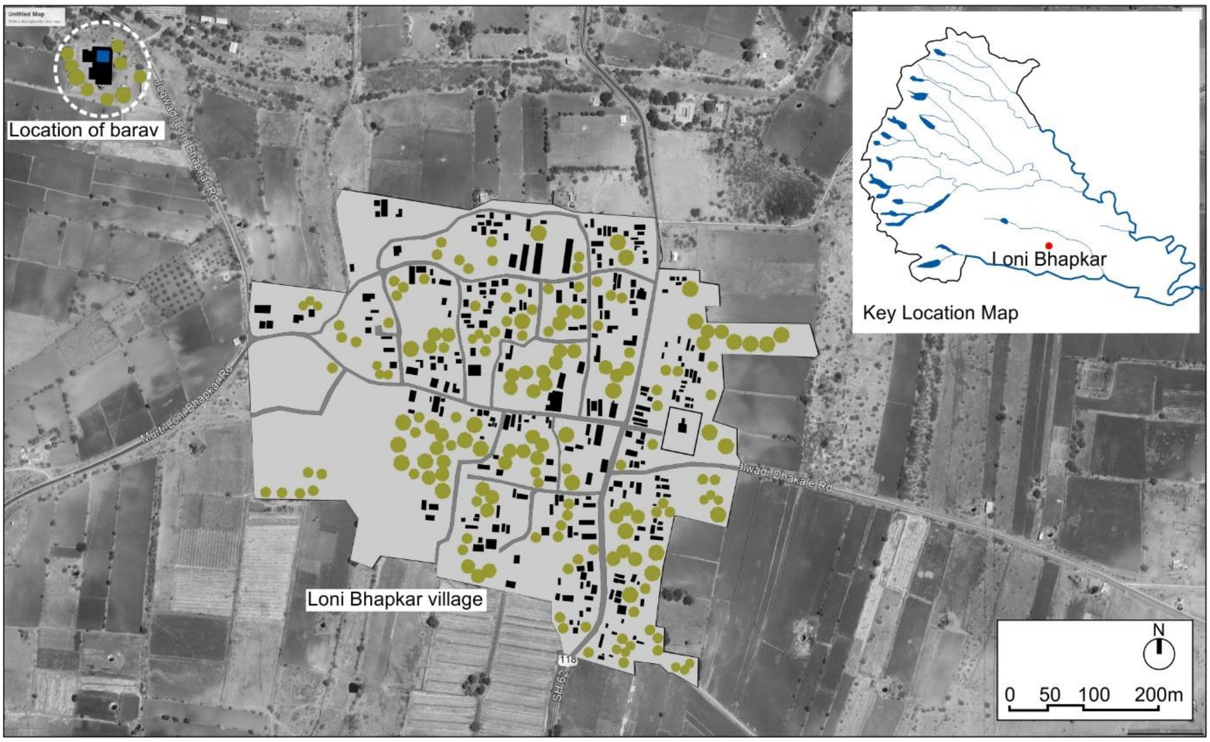

Figure 3.9: Sketch Map of Loni Bhapkar showing the location of Barav.
Source: Data of field research carried on 21-11-2018 superimposed on Google Earth Pro 7.3.2.5491, 08-01-2019. Loni Bhapkar.

The barav at Loni Bhapkar is dateable to the 14th century (Mate, 1998, p.106). As seen in Figure 3.9, the barav lies to the north-west of the present village. It is an integral part of a temple complex located at about 500m away from the village. The temple complex originally consisted of a Shiva temple and a Vishnu temple with a pavilion in its front. In 2000, after the dilapidation of the Vishnu temple, a new Dattatraya temple was built in its place.

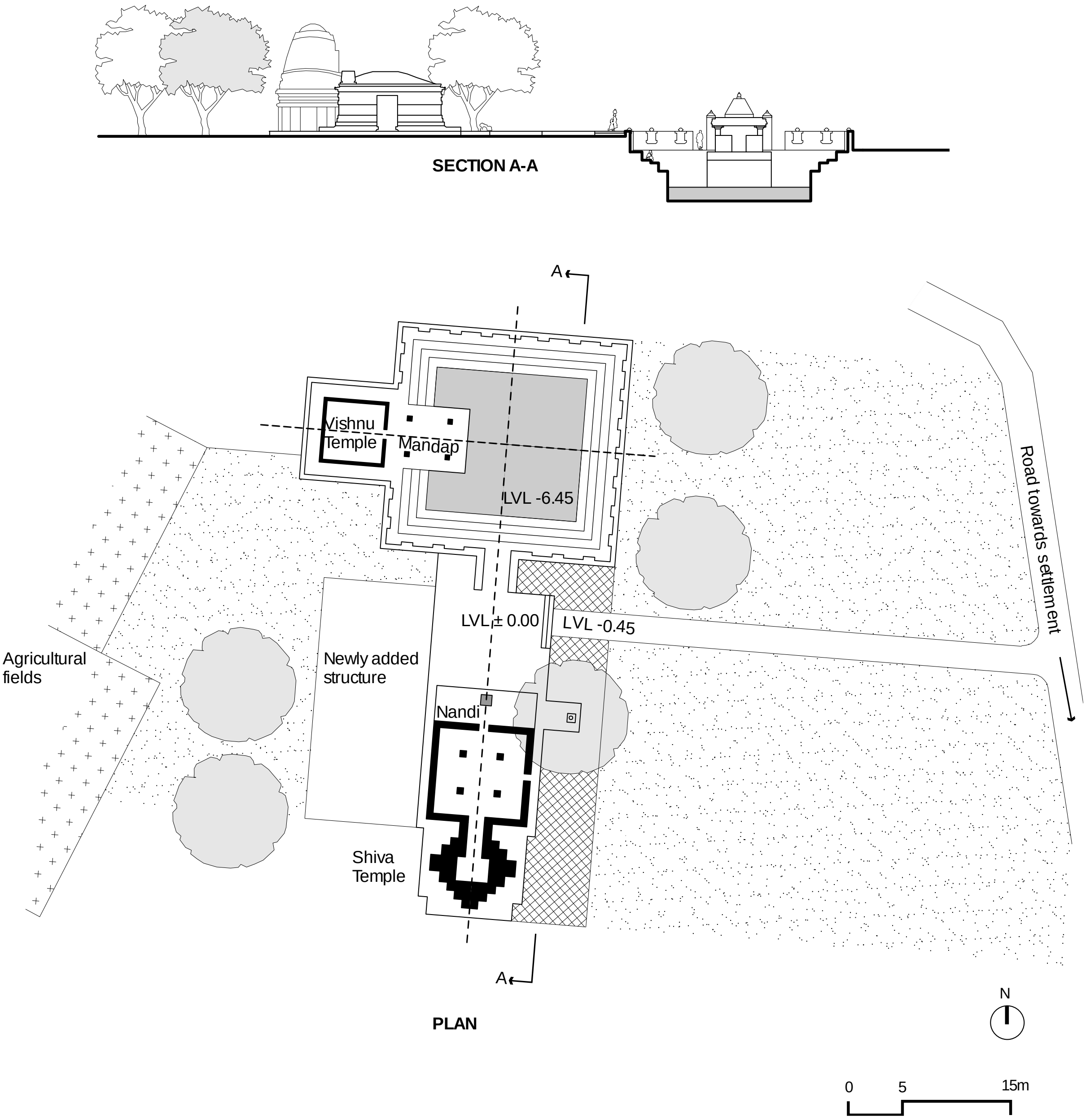

Figure 3.10: Plan and section of the temple complex at Loni Bhapkar.
Source: Author. Field Research carried on 21-11-2018.

As one can see in the case of the temple of Shiva, the deity having a wrathful expression faced away from the settlement, while in the case of the temple of Vishnu, the deity having peaceful expression faces towards the settlement. Furthermore, the deity of Lord Vishnu faced towards the east, so that morning sunrays fall on his face. The falling of sunrays on a deity is an auspicious event according to Hindu belief, and therefore, most of the temples face to the east (Kramrisch, 1946, p.235). The temple complex is raised on a 0.45m plinth that marks its sacred precinct from the village settlement. From the location of the barav, it appears that its water may have been primarily used for bathing purpose before entering the temple.

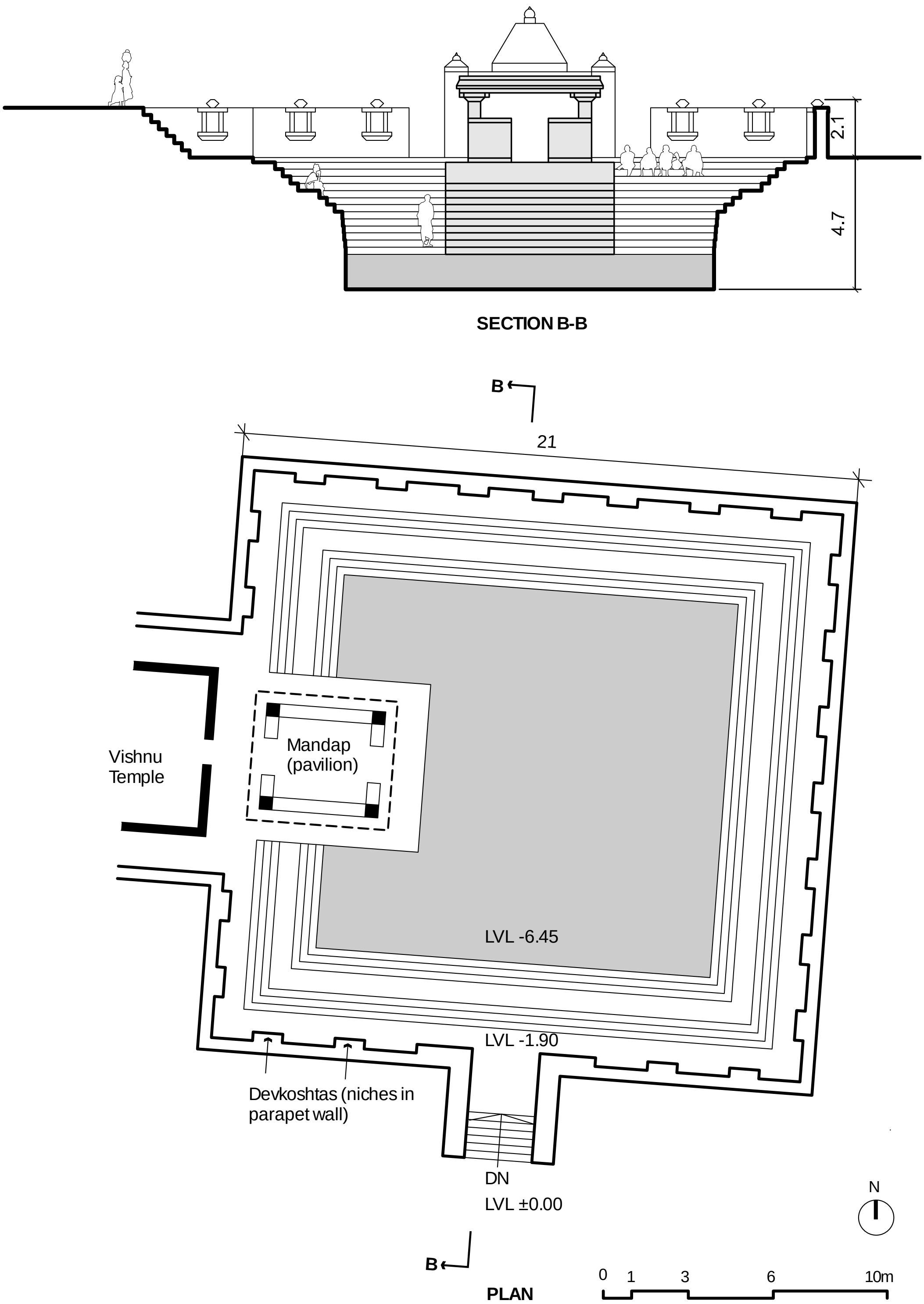

Figure 3.11: Plan, section and photographs of Barav at Loni Bhapkar.
Source: Author. Field Research carried on 21-11-2018.

The Shiva temple is aligned along the southwest-northeast axis while the Vishnu temple is aligned along the southeast-northwest direction. The barav is located at the junction of these two axes (Ref Figure 3.10). The intersection of two axes symbolises the interface between earth and heaven. Therefore, the placement of the barav at the axes junction gives it a symbolic significance. It was essential for the devotees to take a dip in the barav before entering the temple (Dandawate et al., 2006, p.5).

Mandap panel with ornamentation — Niche *(devkoshta)*

Figure 3.12: Features of barav at Loni Bhapkar
Source: Author. Field Research carried on 21-11-2018.

The barav is nearly a square with its side measuring 21m at its topmost part and approximately 14m at its bottommost part. Its overall depth is approximately 4.7m and it has two intermediate landings. A 2.1m high parapet wall is built all along its four sides, with a 2.4m wide entrance located at the centre of its southern side (refer Figure 3.11). A pillared mandap protrudes into the barav to the extent of 6.7m from its western side. The mandap is nearly a square with its side measuring 5m and consists of four circular stone columns that support the stone roof on to their brackets.[36]

A seating arrangement is made in between the columns. The lower portion of the mandap has column motifs carved out on its external surface. The panels in between the column motifs contain figures of mythological deities (refer Fig. 3.12). The mandap probably housed a stone figure of a wild boar, the remains of which lie within the temple precinct.

An important feature of the barav is its parapet wall. It is plain on its external side but contains rectangular niches of size 0.45m x 0.7m on its internal side. The northern and western sides have seven niches each. The eastern side has four niches while the southern side has six niches. Thus, the four sides have 24 niches altogether. These niches housed 24 forms of Vishnu (Dandawate et al., 2006, p.4). Also, there are two more niches at the entrance of the barav. As discussed before, apart from worshipping the deities in the niches, their presence ensured the cleanliness of the place and stored water, highlighting the water management practices of health and hygiene.

Another example of a barav is the one at Manchar, which is not part of any temple complex and was constructed for domestic utilisation of water.

3.5.3. Case example: Barav at Manchar

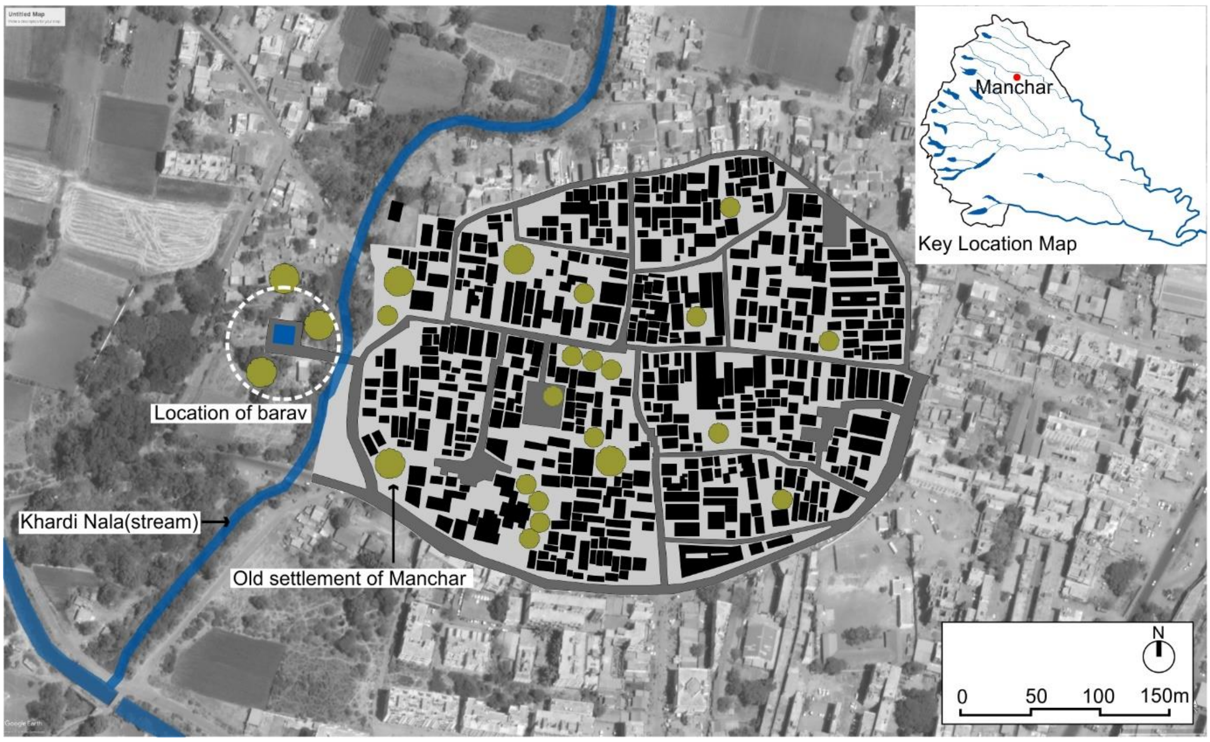

Figure 3.13: Map of Manchar with the location of Barav.
Source: Data of Field Research carried on 29-11-2018 superimposed on Google Earth Pro 7.3.2.5491. Manchar.

[36] Based on observations and measured drawing done during the field research carried on 21-11-2018.

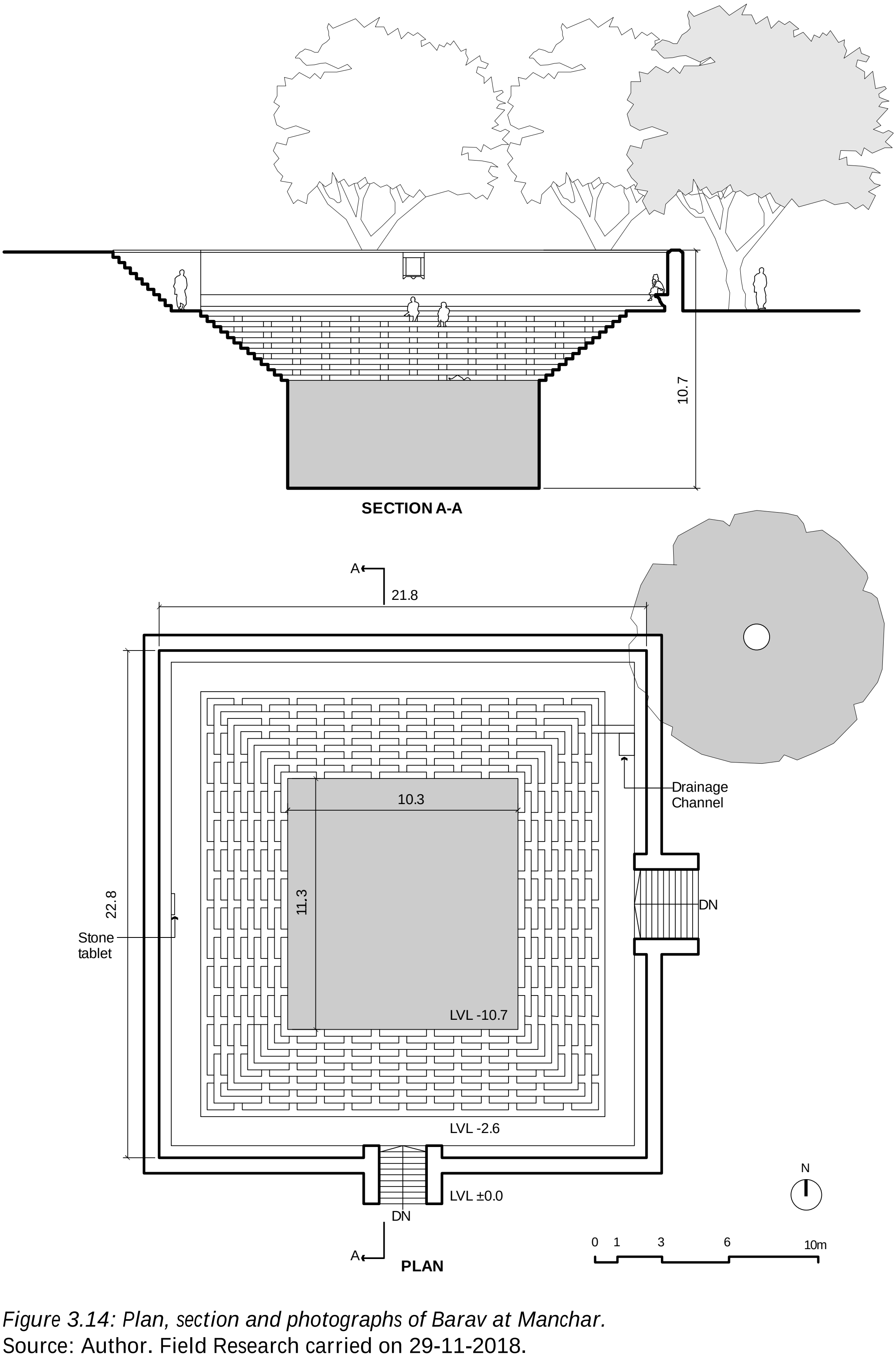

Figure 3.14: Plan, section and photographs of Barav at Manchar.
Source: Author. Field Research carried on 29-11-2018.

The barav at Manchar popularly known as the 'bathing barav' was built during the 14th century. As its name suggests, people use the water from the barav for bathing purpose only. The barav is located towards the west of the present town, near a stream known as *Khardi Nala* (refer Figure 3.13). This location of the barav seems to have a strategic reason. Due to the presence of the stream near the site of the barav, the groundwater table is high, and the barav does not become dry even during the summer months. At the same time, overflow from the barav can be released into the nearby stream (Pathak, 2017, p.67). Unlike most other baravs, this barav is not a part of any temple complex. It was constructed solely for a utilitarian purpose. A stone tablet placed in its parapet wall along the western side mentions that the village head of Manchar constructed it as part of drought relief work.

The barav is nearly a square with its topmost and bottommost sides measuring about 22m and 11m. It has one intermediate landing, and its overall depth is approximately 10.7m. The landing has a 2.7m high parapet wall along its four sides. There are two entrances, one along the southern side and another along the eastern side. A seating platform is present on the first landing. When the level of the water inside the barav rises until the level of the landing, the water escapes through a small channel cut through the parapet wall on the eastern side. The channel releases the water into the adjacent Khardi Nala. This escape channel is a peculiar feature of this barav. Another peculiar feature of this barav is the design of its steps. Each level of steps has a protruding rectangular block of stone after a certain distance. In addition to anchoring the steps, this block forms a platform for seating (refer Figure 3.15). These protruding stone blocks from various levels create an interesting rhythmic pattern.


View of Barav


Detail of steps and water outlet


Stone tablet with Sanskrit inscription mentioning that the village head of Manchar built the Barav in 1344 A.D.

Figure 3.15: Details of Barav at Manchar.
Source: Author. Field Research carried on 29-11-2018.

Both examples of baravs illustrate that they were much more than simple utility structures. Through their design, they enabled people to appreciate and understand the cultural, aesthetic and ecological dimension of water. They offered people the chance to engage with water. Baravs functioned as important meeting points in the daily life of people wherein they could perform their daily rituals, meet and interact with each other in the presence of water. Baravs, in a way, represent the creative imagination embedded in the medieval architecture to instigate socio-spatial and socio-technical interactions.

3.6. Techniques and devices for lifting water

There was a need to lift water from the water storage structures mentioned so far and carry it to individual households and agricultural fields. Wherever water was easily accessible, a person could collect it in a pot and carry it to the intended place over one's head. However, when this was not possible, certain mechanisms had to be utilised to collect and carry water. The ancient text *Arthashastra* by Kautilya (300 B.C. – 100 A.D.) mentions three ways in which this task would be done: i) Carrying water using bullocks, ii) Using mechanical devices to lift water and carry it to the fields through channels, and iii) Using the water wheel for raising water (Srinivasan, 1970, p.381). These three ways of lifting and carrying water differ from different region to region in India and are known by different names.

However, as far as the Deccan region and the state of Maharashtra are concerned, Mate (1998) mentions three common ways of lifting water with the aid of mechanical devices. They were:

a) The Rahat: Drawing water by passing a rope over a wooden drum fixed on an axle in a wooden frame.
b) Rahat gadge: A chain of pots passed over the wooden drum to draw water, similar to a Persian Wheel.
c) The mot: Lifting water using a leather bag pulled by bullocks.

The rahat and mot lead to intermittent or discontinuous water supply, while the rahat gadge leads to a continuous supply of water (Srinivasan, 1970, 382).

3.6.1. The rahat

The rahat is an enlarged and efficient version of a pulley. It consists of a wooden drum with spokes fixed on an axle in a wooden frame (Mate, 1998, p.83). The spokes on the side-wheels of the drum project to serve as handles for rotating the drum. A rope tied to a bucket is passed over the drum. The rotary motion of the drum is used to lower the bucket into the water and to lift it when filled with water. The rotary motion of the wheel facilitates in reducing the effort of the operator. Most of the wells and baravs had a rahat for drawing water. The rahat was a domestic device of lifting water and could lift small quantities of water (ibid).

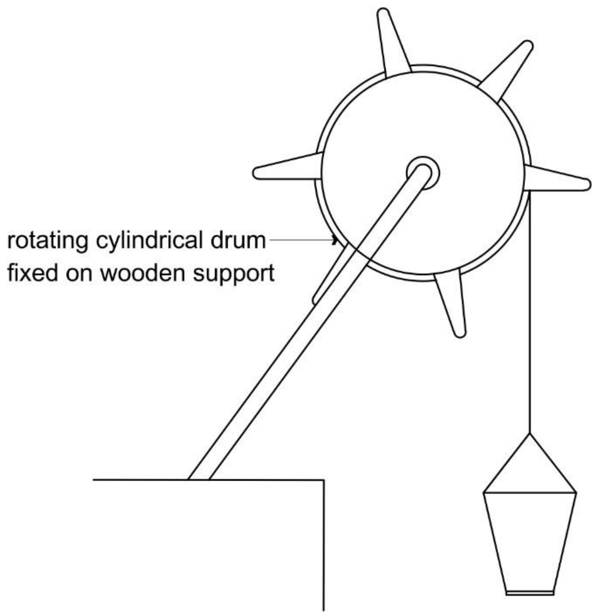

Figure 3.16: Rahat.
Source: Author Adapted from Mate, 2006, p.31.

3.6.2. Rahat gadge

The rahat gadge was a device used for irrigation. Rahat gadge is a mechanical device used to draw water for irrigation. It consists of the wooden drum called rahat around which multiple small pots called as *gadge* are tied all facing in the same direction. The pots are filled with water as they submerge. Due to the rotary motion of the drum, they move upwards and release the water in a trough. As the rahat rotates continuously, pots get filled with water and discharge it continuously in a trough (Mate, 1998, p.83).

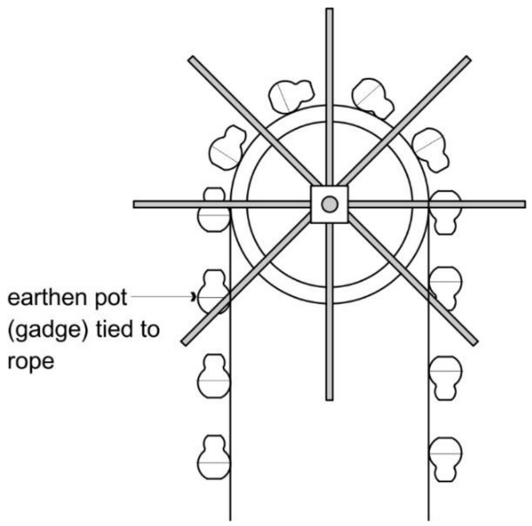

Figure 3.17: Rahat-gadge.
Source: Author. Adapted from Mate, 2006, p.31.

There exist two variations of the rahat gadge. One that is used to lift water from a running course of water like rivers and other to lift water from a still source of water like wells. In the former case, the rahat is placed just above the flowing water. As the pots get filled with water, they are pushed up due to the water current. In the latter case, the rahat is fixed at a certain height near the edge of the well. The spokes of the side wheels are extended to work as handles. Using them, a person would rotate the rahat.

Similar water-wheel technology was prevalent in the Middle East and Europe. Historians of technology use the term *'noria'* for a water wheel (Mate, 1998, p.83). In the arid zones of the Middle East and South Asia, the device is known as 'Persian wheel' (Kennedy and Rogers, 1985, p.84). *Sakia*, *zwafa*, and the *tablia* are some other adaptations of the Persian wheel. Thus, the water-wheel technology was prevalent not only in India but also in other countries.

3.6.3. Mot

The rahat gadge at times would become unsuitable for lifting a large quantity of water required for irrigation. Therefore, in its place, people developed a special mechanism for drawing a large quantity of water from wells with the help of animal power. In the Deccan region, this mechanism is known as mot, where people use bullocks for drawing water from wells. The mechanism derives its name mot from the leather bag used for drawing water (GBP-XVIII, Part I, 1885, p.12-13).

The mot is a funicular shaped leather bag having a broad and a narrow mouth. A thick rope tied to the broad mouth of the mot would pass over a pulley held in a wooden frame. It was placed at the height of around 1.2 to 1.5m above the edge of the well (refer Figure 3.18). Another rope was tied to the narrow mouth of the mot and passed over a small pulley fixed at the edge of the well. The other ends of both the ropes were tied to the yoke of a single or pair of bullocks. The bullock was made to walk back and forth along a path in front of the well. Every time the bullock walked up to the well, the mot would be lowered and filled with water. When it walked away from the well, the mot would be lifted, and the water would be released in a wooden trough. Thus, the linear back and forth motion of the bullock enabled to lift the water from the well.

The working of the mot appears simple at a superficial level. But on close examination, it reveals its ingenuity. The path in front of the well along which the bullock walked, was given a slight gradient away from the well. Therefore, when the bullock had to pull the heavy mot filled with water, its efforts were reduced. These were simple design details, but they reflect the sensitivity of people both towards their domestic animals.

Depending on the quantity of water to be extracted and the weight of the mot, people used either a single or pair of bullocks. Sometimes, people used two or more mots to draw water from wells having large storage capacity. Usually, two operators are required for operating the mot. One to drive the bullock and other to empty the mot into the wooden trough. Although the mot was not a very efficient way of lifting water, it was a reliable way for farmers, who owned bullocks (Kennedy and Rogers, 1985, p. 81).

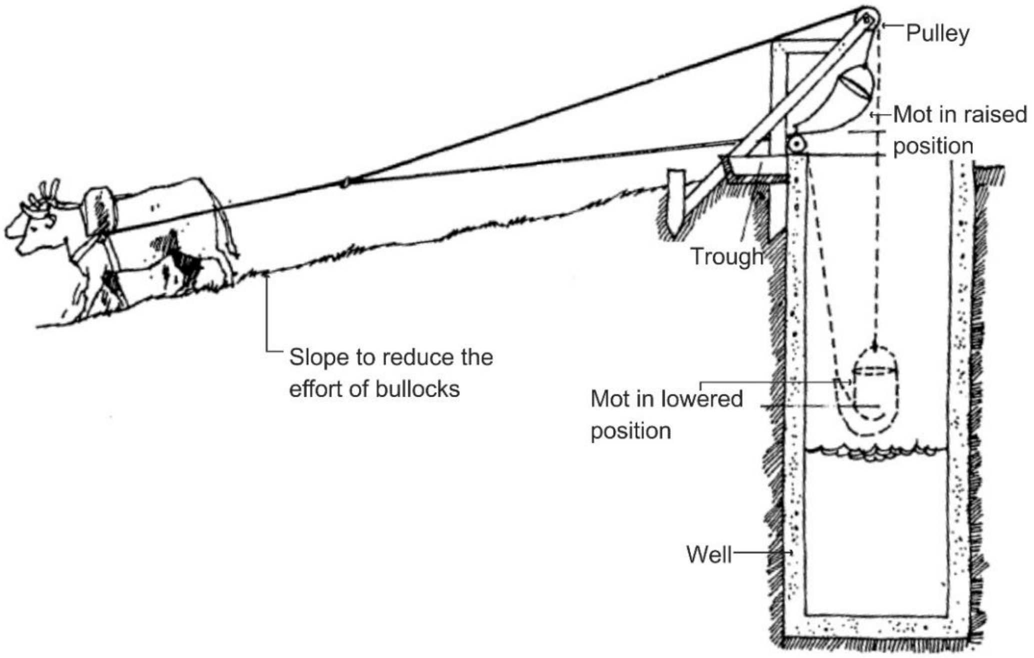

Figure 3.18: Mot.
Source: Adapted from Barah, 1996, p.52.

Thus, depending on the purpose, the rahat, mot or rahat gadge were used to lift water. Srinivasan (1970) states that it is possible for similar mechanisms to have co-existed at different places and were known by different names (Srinivasan, 1970, p.386)

3.6.4. Conclusion

The main aim of this chapter was to understand the sacred and artistic ideas embedded in the water harvesting practices and structures that make them valuable beyond their utilitarian purpose. The following conclusions can be derived from the various examples discussed in this chapter:

Location specificity and understanding of geology and hydrology

We observe that people designed the different water storage structures discussed in this chapter after careful inspection of the site conditions. For instance, the artisans dug podhis at precise locations where rainwater trickling down the hill slopes would accumulate. Similarly, people built baravs where the groundwater was available at a depth of 7m to 10m. These examples highlight the fact that the people in ancient times possessed knowledge of geology and hydrology through their everyday interaction with their surroundings. Some of this knowledge was later written down in the scriptures. Most of the traditional water storage structures are location specific. They suit the topographical conditions of the place where they belong. Therefore, replicating them as they are elsewhere is difficult. This location specificity also makes these structures diverse. Two structures located at two different places would be similar but rarely the same. Location specificity and a thorough understanding of the site conditions are two important reasons for their survival for more than eight hundred years.

Water structures marking secret precincts

Almost all the examples of water structures discussed in this chapter have a well-defined edge which separates the territory of water from the territory of land. This territory of water is sacrosanct, and people are expected to respect its sacredness. For instance, the taakis have a parapet wall demarcating its edge and at the same time preventing outside impurities from entering into the water. Similarly, baravs have a 1m to 2m high parapet wall that demarcated its edge and prevented dust and impurities from entering into it. Besides, the wall also hid the inner beauty of the stepped pattern of steps of the barav. It thereby created an element of surprise as one entered into the barav through its entrance. Also, the devkoshtas inside the barav with figures of deities added to the sacredness of the water structures, thereby including the design aesthetics that exceeded its initial utilitarian purpose.

Detailing of water structures and water lifting devices

The structural detailing of podhis, taakya and barav made them withstand various forces such as the soil pressure, hydraulic pressure and the self-weight. Additionally, the robust design of the water storage structures has enabled them to survive and function even after eight hundred years.

The design of water structures was such that people could see water during all the seasons. This was helpful in gauging the availability of water before the outset of the monsoon, thereby helping in adjusting the water consumption accordingly. Thus, visual interaction and prior knowledge on water collection played a critical role in sustaining resource sensitivity.

Along with water sensitivity, people were equally aware and sympathetic to their domestic animals. Even while drawing water from wells by a mot, people attempted to reduce the effort of the bullock by providing a ramp. All these details exhibit the ecological sensitivity and traditional knowledge of the ancient people.

Water structures as social spaces

The design of the water structures is such that it invites people to pause, spend time near water and experience its pleasures. The verandah in case of the Kamani Taake serves as a seating place that is shaded and cooler than the outside. Similarly, the barav at Loni Bhapkar has a mandap with a seating arrangement for people to interact and spend time near water. In the case of the barav at Manchar, the steps themselves are designed in a manner that they act as seating platforms. They create beautiful shadow patterns during different times of the day. Every time as the water rises or recedes, steps hide or reveal themselves creating a pleasurable experience every time. It transcends being a technical artefact by incorporating aesthetic merit that allows for the structure to develop a social function.

The sacrosanct ideology is common throughout all the different water structures. Sometimes, the water harvesting practices, structures and techniques helped in sustaining water as sacrosanct due to its limited availability. However, the 14th century saw a regime change in Pune. The Deccan Sultanates coming from Persia started ruling over Pune. Under these dynastic rulers, the Hindu culture was exposed to Persian technology. As a result, the water architecture from 14th century onwards shows variance in design features. The following chapter discusses this change in the design of water structures from 14th century onwards.

4. Water begins to flow: Nahars, talavs and kunds

This chapter examines the influence of Persian technical knowledge on the traditional water structures of Pune during the 14th and 18th centuries. It attempts to understand the working and features of three types of structures: nahars, talavs and kunds. The observations show that these water structures mark the beginning of infrastructure systems, i.e. they are not individual stand-alone storage media alone, but a network of different components that store and distribute water. They are sacred, aesthetic, and at the same time, integrated into the settlement fabric. In conclusion, the chapter highlights the criticality of these water systems in the spatial development of Pune.

4.1. Introduction

Rainwater and groundwater storage structures like wells, kunds and baravs were built in Pune during the early medieval period. However, Pune witnessed new ideas and ways of water management in the late medieval period that came in through the Deccan Sultanate dynasties of Persia and the Middle East. The Deccan Sultanates were more concerned with the flow of water rather than its storage and therefore attempted to bring water up to the people through subterranean tunnels rather than people fetching water (Mate, 2006, p.47). They had the technological know-how of constructing such tunnels, commonly known as qanats in the Middle East. The earliest known qanats dating back to the 8th century B.C. are found in Iran. From, Iran, the technique of building qanats spread throughout the Middle East and Mediterranean (Hodge, 2000, p.35).

Thus, the Deccan Sultanates designed tunnels similar to qanats called nahars in different towns of Deccan such as Ahmednagar, Aurangabad, Bijapur and Daulatabad (Mate, 1998, p.127). These systems worked well and soon became an integral part of their settlement fabric. These nahars, in turn, inspired the Peshwe rulers who suitably adapted them for Pune. Similarly, other storage structures such as hauds and talavs became part of Pune's landscape. This chapter thus aims to understand water structures that influenced the landscape of Pune during the 18th century. It attempts to answer the following questions:

What were the salient features of nahars, talavs and kunds, and how did they function?

What changes did they bring in the water management practices and landscape of Pune?

The chapter undertakes the case examples of TWI built from the 14th to 18th century for answering the above questions. For analysing the development of nahars within this timeframe, it is convenient to divide it into three periods:

i) The Deccan Sultanate period (14th – mid 17th century) wherein the rulers adapted the qanat system to design nahars in the cities of Deccan like Ahmednagar, Bijapur, Aurangabad, and the Junnar Taluka in Pune.

ii) The Maratha period (mid-17th – early 18th century) where the Maratha kings and especially Shivaji (1627-1680 A.D.) kept a check on the invaders, repaired existing groundwater structures, built new taakya and talavs and encouraged irrigation.

iii) The Peshwe period (early 18th – end 18th century) where the Peshwe designed an elaborate nahar system for Pune.

As far as the research area of Pune is concerned, the Gazetteer of Bombay Presidency (1885) mentions the existence of an early nahar system at Junnar town during the rule of the Deccan Sultanates. It does not mention the existence of nahars elsewhere during their rule. Since Junnar was located along the trade route to Konkan, as mentioned in the previous chapter, it was already a developed medieval town during the 14th Century (GBP-XVIII, Part-III, 1885, pp.224-225). Therefore, the Deccan Sultanates made it the capital of their empire for a brief period in the 15th and 16th centuries and built a nahar system for fulfilling its water requirement. At that time, Pune was just a small settlement consisting of a few houses belonging to a few artisans. As the water requirement was limited due to less population, there were many wells but no water system as such in existence.

It was only during the Maratha period under the able leadership of Shivaji (1650-1680) that Pune once again became a habitable place. However, Shivaji and the succeeding Maratha rulers were engaged in establishing *Swarajya* (self-rule and self-governance) by freeing regions from the rule of the Deccan Sultanates (Kurkute, 2018, pp.86-87). They were constantly engaged in warfare and establishing a strong defence system. Therefore, they were unable to undertake any major water infrastructure works. Instead, they repaired the existing taakya and talavs for having adequate water on the forts during warfare as well as for irrigation in villages (ibid).

Later, in the 18th century, Peshwe rulers made Pune as their capital. From there onwards, they transformed it from a small settlement to a developed medieval town with necessary amenities (Gadgil, 1945, pp.14-15). It had four nahars bringing water from different locations. The Peshwe also built talavs and kunds for storing rainwater and groundwater. The talavs built at Jejuri and the kunds built at Ranje village are the surviving examples of their contribution towards water management.

These three important transitions in the design of water structures and systems have been indicated in Figure 4.1.

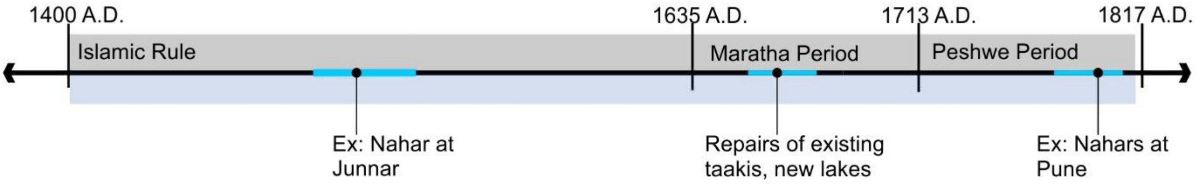

Figure 4.1: Timeframe indicating the examples of water management from 1400 A.D. to 1800 A.D. Source: Adapted from Sowani, 2011, pp.25-32.

The following section 4.1 briefly introduces to the subterranean nahar system of Deccan. It first takes an overview of the Qanat system of water management in Iran as the idea behind the evolution of nahars in Deccan. Further, it elaborates on the working of nahar and its components. In the end, it gives a short overview of the nahars found elsewhere in other towns of Deccan.

Section 4.2 discusses the nahar at Junnar. Here, the nahar is in its initial stage of evolution. The example of Junnar serves as a first step in understanding the more elaborate and extensive system of nahars at Pune.

Section 4.3 discusses the nahars developed by the Peshwe and their ministers at Pune. Here, the emphasis of the discussion is on understanding the contribution of nahars in enhancing the landscape and image of Pune.

Section 4.4 explores the rainwater storage lakes called as talavs designed by the Peshwe at Jejuri. These talavs had a dual purpose. As water storage structures, people went to their banks for fetching water. Besides, they were also sources of water supply for a small length of nahars that supplied water at few places within Jejuri. This section also explores the kunds at Ranje village that are located within the premises of a temple. The unique feature of these kunds is their design that prioritises water use – first for drinking, then for bathing and washing, and finally for agriculture. Lastly, the chapter summarises the main findings from the case examples and describes the way nahars brought about a change in the landscape of Pune.

4.2. Nahars: Their origin, adaptation and spread

The Deccan Sultanates built some of the initial nahars at the Deccan towns of Ahmednagar, Bijapur and Aurangabad. The nahar at Ahmednagar is the oldest of all, completed in the first part of the 16th century (Mate, 1998, p.128). Salabat Khan, a Turkish engineer, built it during the reign of Ahmad Nizam Shah (1490-1508) (Garge, 2018, p.44). Altogether, 15 nahars brought water to the settlement of Ahmednagar from a distance of 20km to 30km (Deshmukh, 2018, p.41). Ali Adil Shah I (1557-1580) completed the nahar at Bijapur during his reign (GBP-XXIII, 1884, p.579). After him, Sultan Mahmud (1626-1656) built a talav called the Begam Talav that carried water to many gardens and fountains within the city (GBP-XXIII, 1884, p.589). Malik Amber built the nahar at Aurangabad in the late 17th century. It is famously known as the Nahar-e-Ambari after him (Garge, 2018, p.44).

Within Pune district, the town of Junnar had a nahar system in the mid-16th century. It was built during the reign of Murtaza Nizam Shah I (1565-1588) (Kharmale, 2016b). After Junnar, Peshwe Balaji Bajirao (1740-1761) laid the Nahar-e-Katraj at Pune during 1749-1755 (Sowani, 2017, p.124). It was an elaborate system of water supply altogether 8-10km in length. Some other ministers at the court of Peshwe built nahars towards the end of the 18th century. Altogether, Pune had four nahars that brought water to Pune from different places around its periphery. While construction of nahars originated in the period of Deccan Sultanates, it was noticeably absent in the Maratha Period and saw re-emergence in the Peshwe Period.

The qanat system in Iran and Persia influenced the construction of the nahar system in Deccan. Therefore, it is essential to have a brief overview of the qanat system for understanding the nahar system.

4.2.1. Overview of the qanat system

Iran, where the oldest qanat can be found, is an arid land with average annual precipitation of 273mm (Ahmadi et al., 2010, p.125). This precipitation is far less in comparison to the world average annual precipitation (about 33% of 814mm, which is the world average). To best utilise the available precipitation, the Iranians invented several methods for storing and transporting both surface water and groundwater. One such method of extracting groundwater is the qanat system. It captures the groundwater from an upslope area where the water table is close to the surface and transports it to a flat arid terrain through underground tunnels (Hodge, 2000, p.36). Availability of water makes the arid land habitable and suitable for cultivation. In laying out the qanat system, a shaft is first dug in an upslope area until it reaches the permanent water table. This shaft is called the mother well. The length of the qanat is measured from the mother well to the point where water is to be received at the surface. The usual gradient for the qanat is approximately 1:1000 or 1:1500 (English, 1968, p.173). After fixing the receiving point based on the gradient, the tunnel is dug back towards the mother well. While digging the tunnel, vertical shafts connecting the tunnel to the surface are dug at a distance of about 20m. Sometimes they could be as close as 5m apart (Hodge, 2000, 37). These tunnels, therefore, appear as a dotted string in the landscape of Iran. Their purpose is to ventilate the tunnel for the workers and enable them to remove the debris out of the tunnel. After completing the tunnel up to the mother well, water gently flows to the desired receiving end by gravity.

Qanats were first constructed in Iran during the first millennium B.C. During the rule of Achaemenid Persians (550-331 B.C.), the knowledge and technology of constructing qanats spread to Mesopotamia, Egypt, parts of Africa, Afghanistan and parts of Central Asia. Later, through the early Arab invasions in the 7th century, the technology spread to North Africa, Cyprus, Italy, Spain and Latin American countries like Mexico, Peru and Chile (Ahmadi et al., 2010, p.127).

Old qanats have also been evidenced at Rome. Although the technology of constructing qanats is similar in the Middle East and Rome, Hodge (2000) observes a primary difference in the intention behind their construction. In the Middle East, people built qanats for their basic sustenance. Usually, the qanats were planned first, and settlements came later around the receiving end of the water. Conversely, Romans built qanats more as a luxury to have public baths. The settlement always existed before, and the qanats were built later (Hodge, 2000, p.38).

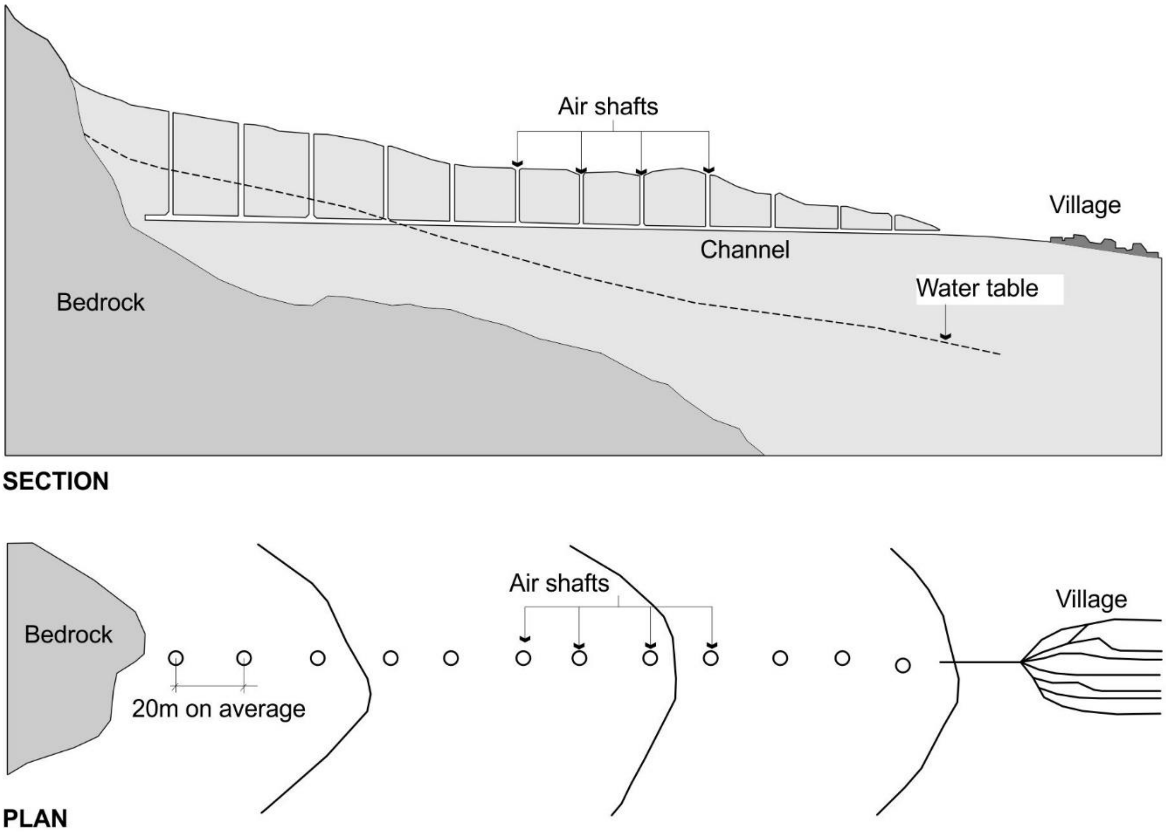

Figure 4.2: Diagram of the qanat system of water management.
Source: Adapted from English, 1968, p.171.

In the context of India, the Deccan Sultanates introduced the qanat building technology to the Deccan region in the early 16th century (Deshmukh, 2018, p.39). It became known here by the name of 'nahar'.[37]

The lack of a perennial water supply system in towns of Deccan prompted the Deccan Sultanates to build nahars. However, while building nahars, they seem to have adapted the original qanat building technology so that it suits the context of Deccan. The towns mentioned

[37] Nahar is a Persian word, which means a river.

above are located in a shallow locus surrounded by hills. Their location becomes favourable for bringing in water from a high land by gravity (Mate, 2002, p.96). Nahars, therefore, follow the same basic principle for transporting water that the qanats follow in Iran. However, while the tunnels of qanats may be as deep as 300m below the ground surface, the tunnels of nahars are around 10m-12m below the ground surface. In addition, almost all qanats carry groundwater, while nahars carry groundwater as well as surface water stored in talavs (Gokhale, 2018). The difference in the climatic and geological conditions of Iran and Deccan could probably have led to these minor adaptations of the qanat system.

4.2.2. Parts of the nahar

A nahar system transports surface water or groundwater from a higher to a lower terrain under gravity. It typically consists of the components indicated in Figure 4.3.

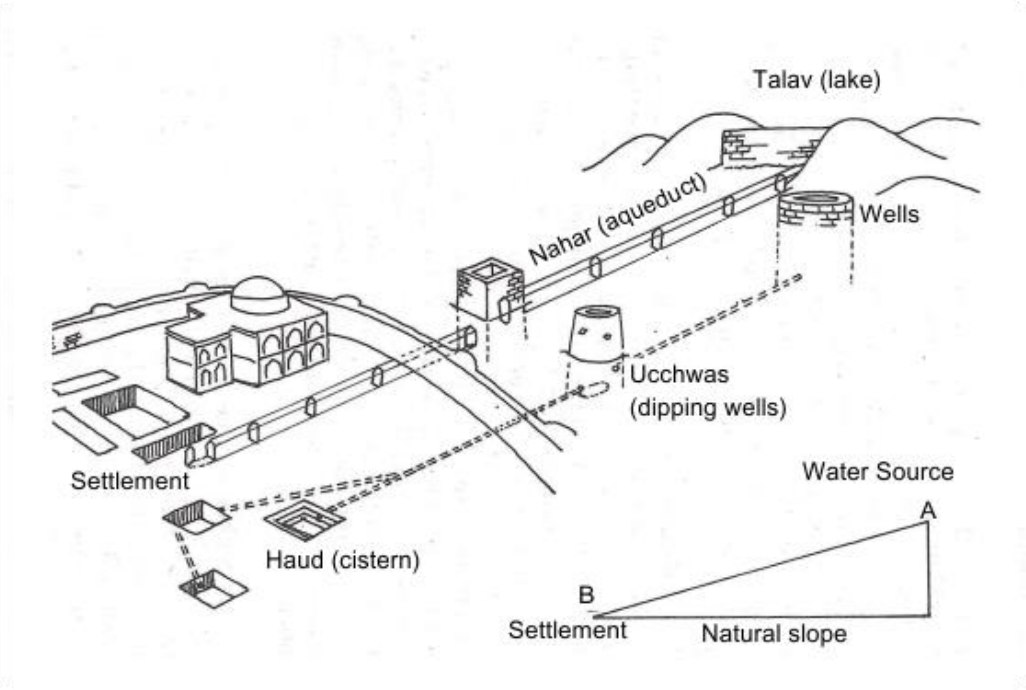

Figure 4.3: Sketch illustrating the parts of a nahar.
Source: Adapted from Mate, 1998, p.44.

<u>Water source</u>: In the case of groundwater, the source is a well called as a '*vihir*' or '*bavdi*'. In the case of surface water, the source is an artificial tank known as '*talav*'.

<u>Aqueducts</u>: Water from the source is carried through underground tunnels lined with either bricks or stones. They are called as '*nahars*'. Often, the Marathi word '*nal*' is used instead of nahar. However, more specifically, it is used in cases where water is carried through earthen, brick or stone pipes.

Airshafts or dipping wells: These help to release air pressure from the nahars. At places, they also collect the silt from the water, which could be removed periodically during the maintenance of nahars. They are called as *'ucchwas'* meaning to exhale out due to their function of releasing air pressure.

Cisterns: Water from the nahars is collected into masonry cisterns known as *'hauds'*. They are usually located below the ground surface.

Thus, the talavs (or vihirs or bavdis), nahars, ucchwas and haud together constitute the nahar system. After understanding the basic functioning and parts of the nahar system, the next section examines the nahar system at Junnar.

4.3. Bavdis and nahars of Junnar

4.3.1. Origin

The strategic location of Junnar as one of the towns along the trade routes was discussed in the previous section. Due to its strategic location, it was also the capital of the Nizam Shahi dynasty for two short periods from 1490 to 1494 and 1605-1637 (GBP-XVIII, Part-III, 1885, pp.225-226). There was a need to have a reliable water supply system to facilitate the growth of Junnar, encourage people to settle down and fulfil their water requirement. Therefore, Murtaza Nizam Shah laid the nahar system in the mid-16th century.

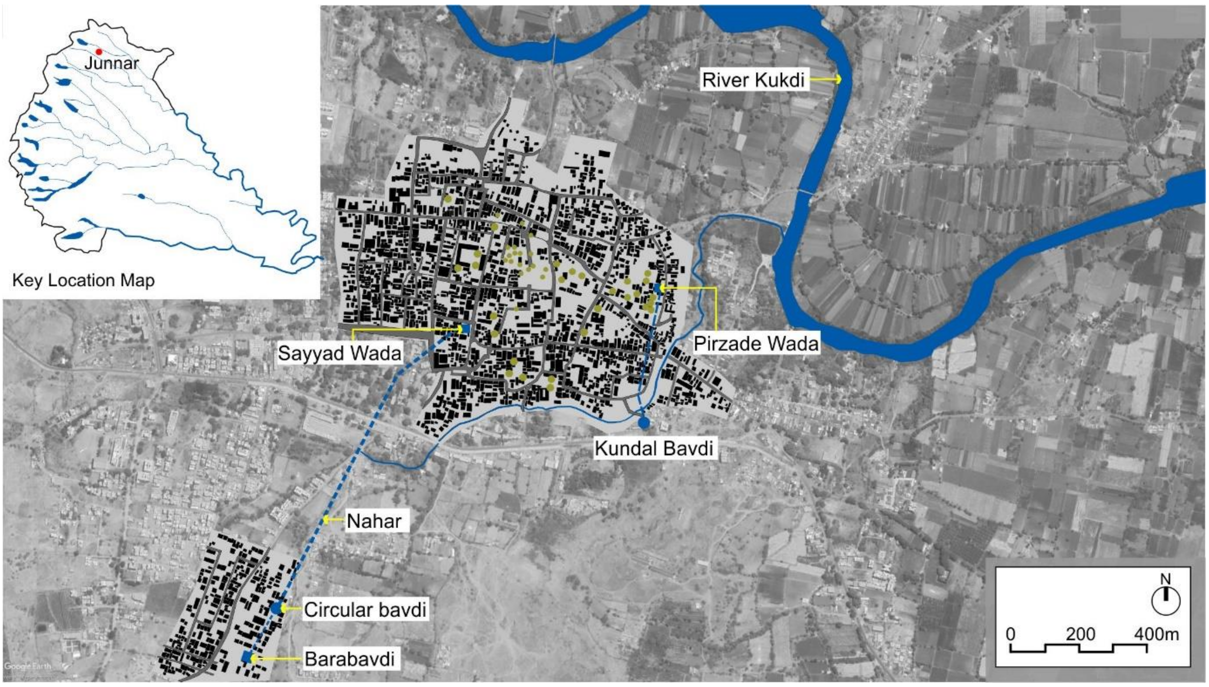

Figure 4.4: Nahar system marked on the map of Junnar.
Source: Final Development Plan of Junnar (Revised), 2010.

The settlement of Junnar is spread over a distance of about three kilometres in between the River Kukdi to the north and flat-topped hills towards the south (GBP-XVIII, Part-III, 1885, p.140). People utilised the water of Kukdi for irrigation as well as household purposes. However, Kukdi being an intermittent river, the Nizam decided to have a reliable source of water by bringing water to the settlement from the foothills located towards its south. He commissioned workers for digging two bavdis at their foothills and bringing their water up to the settlement through nahar. From the nahar, people collected water in hauds spread across the settlement. The Gazetteer of the Bombay Presidency (1885) mentions that altogether three bavdis located towards the south of Junnar supplied water to 18 hauds through nahars (GBP-XVIII, Part-III, 1885, p.146). Out of these three bavdis, one known as the Barabavdi and another one connected to it by a nahar exist even today and supply water to the haud at Sayyed Wada. Besides, there were three other bavdis supplying water to the settlement. Out of these other three, one known as the Kundal Bavdi still supplies water to a mosque in Pirzade Wada. Even a few ucchwas exist near the settlement. Thus, the entire system is made up of bavdis, nahar, ucchwas, and hauds.

4.3.2. Parts of the nahar system

<u>Bavdis</u>

Barabavdi is located to the south of Junnar. It is connected to a circular bavdi located about 200m towards its north through an underground channel. Together they continue to supply water to the hauds in Sayyed Wada. The Barabavdi is 9.3m x 10.7m rectangular well with a depth of around 10m. It has a 0.5m wide and 1m high parapet wall around it with an entrance on the southeastern side. From here, one can access its water by climbing down 34 steps. The first 30 steps are 0.3m wide and 0.2m high. The remaining four steps are more like landings that are about 2m wide and equally high as the earlier steps.

On its northeastern side are two round openings about 2.5m above the bottom of the well. These openings are outlets that carry water from it into the connected circular well. The Barabavdi thus functions as a settlement tank; wherein water is stored temporarily for some time until the silt and dirt settle down and clean water flows into the second well. The second well is a circular well with a diameter of about 5m and depth around 13m. It has a 0.6m wide and 0.2m wide parapet wall around it with a circular flight of steps leading to the level of water. There is a stone screen at its inlet to filter the water. From this well, water was carried to different cisterns and fountains in Junnar. The Sayyad Wada still receives water from the two wells.[38] The Barabavdi is partly constructed using stones from old Hindu temples. Kharmale (2016a) believes that two Hindu temples existed near the bavdis. The Deccan Sultanates destroyed them and utilised their ornamental stones in the construction of the bavdi.[39]

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[38] Kharmale, 2016a; Field Observation by Author on 27-11-2018.

[39] Whenever the Deccan Sultanates captured a particular place in Maharashtra, they destroyed the Hindu temples and Hindu idols at that place as a symbol of their religious and political dominance. The Deccan Sultanates also

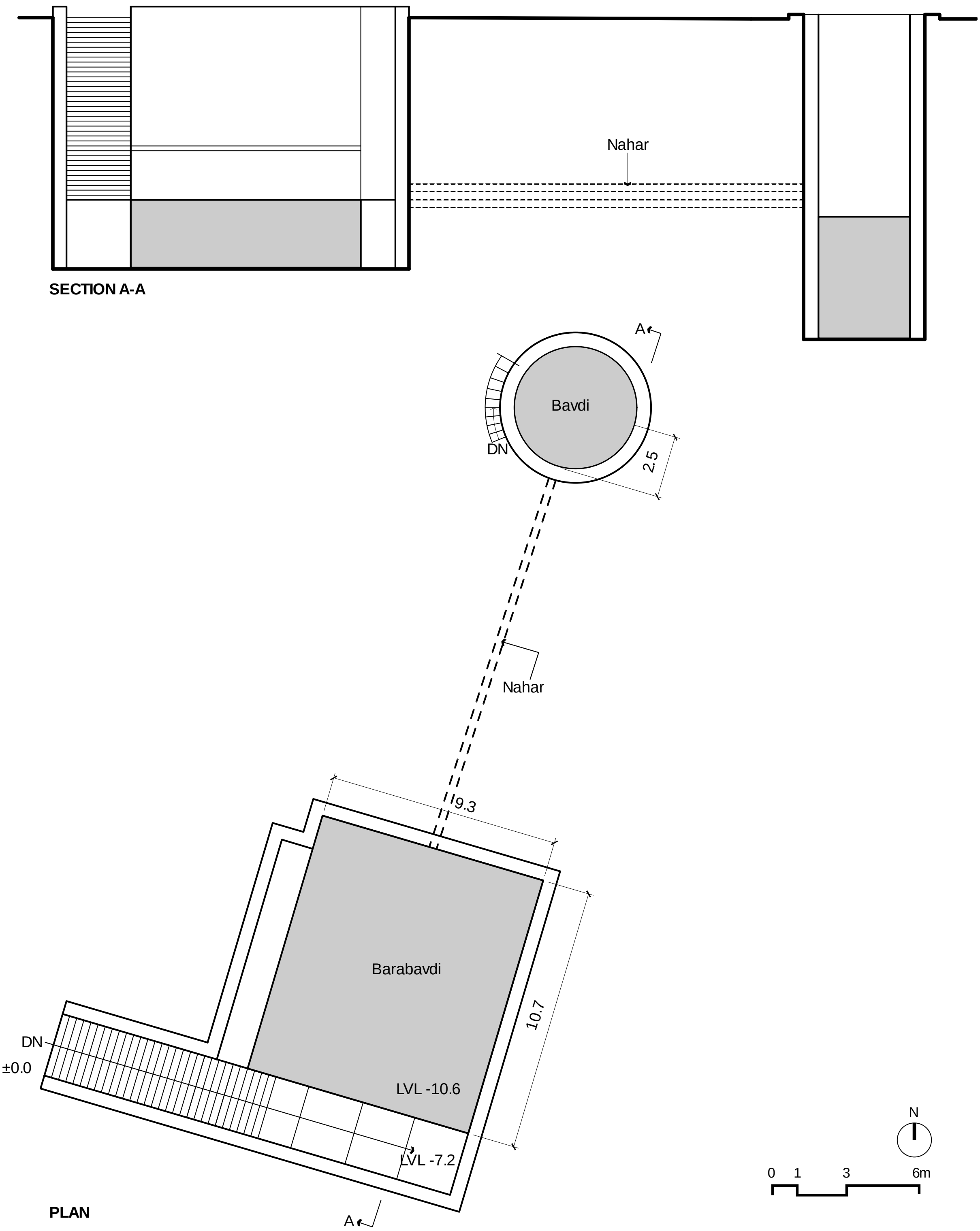
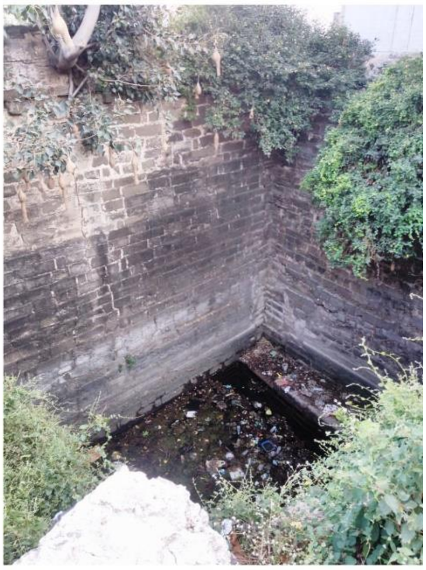


Figure 4.5: Plan, section and photograph of Barabavdi, Junnar.
Source: Author. Field Research carried on 27-11-2018.

destroyed the Punyeshwar and Narayaneshwar temples situated on the banks of the Mutha in 1290 A.D. (Joshi, 1868).

Circular Bavdi connected to Barabavdi



Barabavdi

Figure 4.6: Circular bavdi and Barabavdi, Junnar.
Source: Author. Field Research carried on 27-11-2018.

In addition to the Barabavdi and the circular bavdi, another bavdi known as the Kundal Bavdi is located towards the southeast of Junnar. It is a circular well with a diameter of about 10m. Its parapet is in ruins. Towards the south of the well, is a flight of steps that runs halfway up to the water and then turns towards the west. From here, the nahar carries water to a mosque within the Pirzade Wada where it is stored in two hauds.

The construction of Kundal bavdi is done using massive stone blocks, each weighing about 100kg (GBP-XVIII, Part-III, 1885, p.148). They interlock in each other. No mortar is required for holding them together. This construction style is known as the *Hemadpanti* [40] style of construction. Being a Hindu style of construction, it was popular during the time of Yadavas who ruled Junnar before the Nizamshahi rulers. Therefore, the Kundal Bavdi may have existed even before the Nizamshahi. The Nizamshahi rulers may have repaired it using the stones from the temple and laid the nahar that carried water from the Kundal bavdi into the various hauds in Junnar.

<u>Nahar and ucchwas</u>

The nahar is in the form of a tunnel around 10m below the surface of the ground. Its height is 1.8m, comfortable enough for a person to walk through it for maintenance purpose (Kharmale, 2016a). At specific intervals along the nahar, there are ucchwas. They are dug 2m to 3m below the bottom of the nahar. Any impurities or dirt would settle down in them and clean water would flow ahead. Persons responsible for cleaning would enter and clean them periodically.

[40] The style is named 'Hemadpanti' after its founder designer Hemadpant (1259-1274 A.D.) who belonged to the court of the Devgiri Yadavas.

Not many ucchwas survive today, but one such square ucchwas with side 1.3m is present near the Barabavdi.

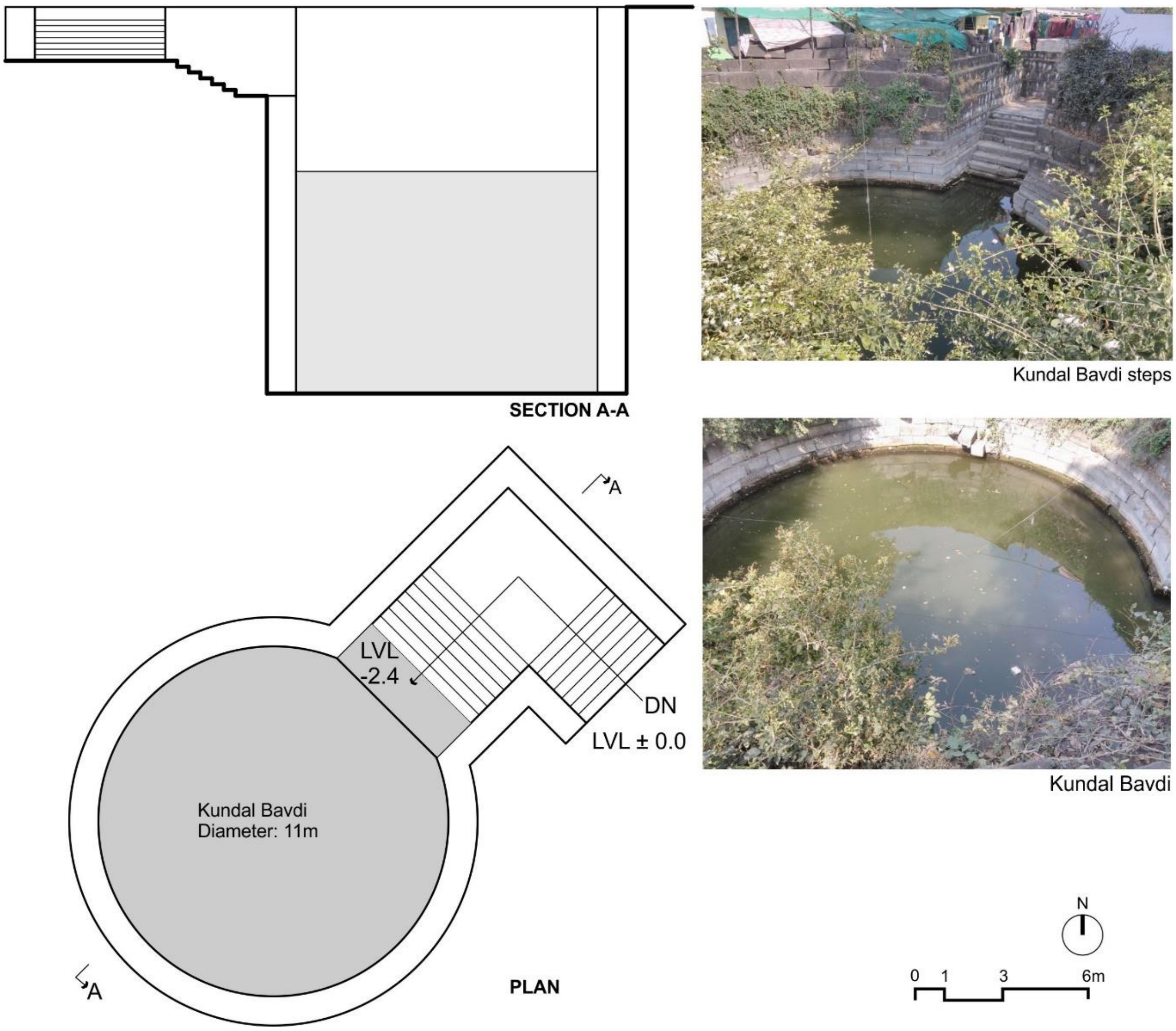


Figure 4.7: Plan, section and photograph of Kundal Bavdi, Junnar.
Source: Author. Field Research carried on 28-11-2018.

Hauds

Hauds stored water from the nahar. Out of the 18 hauds mentioned before, one haud still receives water from the Barabavdi. It is located in the premises of a residence called Sayyad Wada. It is a square with 4.8m side and 3m depth (See Figure 4.8). Two other hauds present in the Pirzade Wada collect the water coming through the nahar of the Kundal Bavdi. One of them is a 5.7m x 4.0m rectangle having a depth of about 3m, and the other one is a square with 1.2m side and 1m depth. The square one is relatively smaller and stores less water as compared to the rectangular haud. A characteristic feature of all the three hauds is that they have a 15cm wide and 7.5cm deep channel around them for draining away the excess water that overflows into it. The channels connect to a bigger underground channel that carries the water away from the town.[41]

[41] Based on Field Research carried on 27-11-2019.

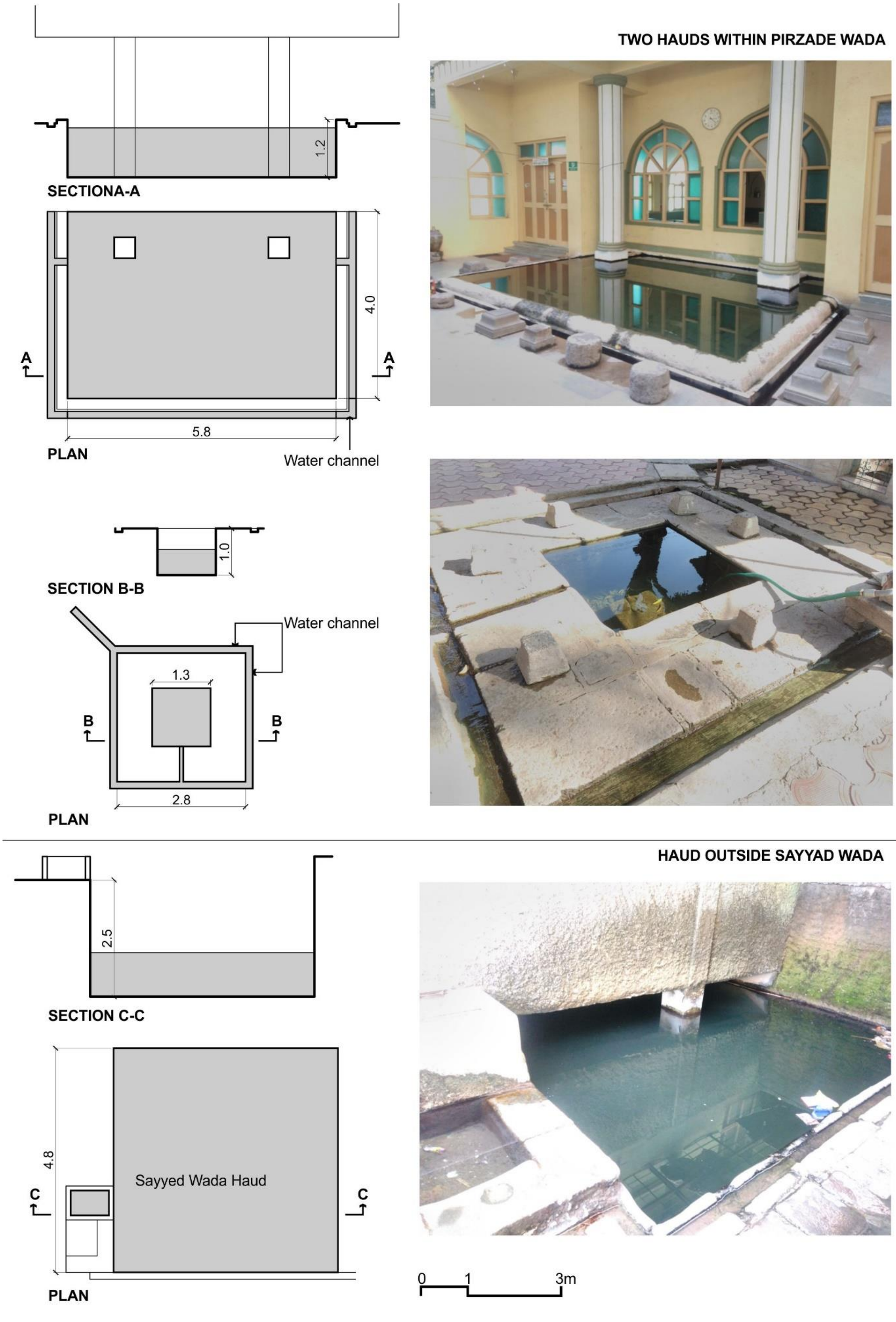


Figure 4.8: Plan, section and photographs of hauds, Junnar
Source: Author. Field Research carried on 28-11-2018.

The entire system of bavdis, nahar, ucchwas, and hauds continues to function partly even after four hundred years. The system, built in the mid-16th century, is first of its kind in Pune region wherein water was brought to a town by nahars. The main emphasis while designing the system seems to be on the functional dimension of the system and less on the aesthetic dimension. Therefore, the bavdis and the hauds are devoid of any ornamentation. Nevertheless, the system emerged from a thorough understanding of the natural terrain and utilised the natural gradient of the land to transport water to far off distances, highlighting the Deccan Sultanate rulers' knowledge of hydraulics.

In comparison to the nahar system at Junnar, the one designed by the Peshwe rulers is much more elaborate and well worked out nahar system for Pune during the 18th century. Before examining it, it is important to take an overview of the water supply and irrigation work undertaken by the noteworthy Maratha ruler Shivaji. He encouraged people to repair several preexisting groundwater structures on the hill forts of Deccan and to undertake irrigation works. He also established a farmer-friendly revenue system (Majumdar, 1977, p.536). The following section examines his ideas and contribution to water management.

4.4. Shivaji's water management work

The Deccan Sultanates often plundered and destroyed many towns in Deccan. Pune faced severe destruction during the 16th and early 17th centuries. Murar Jagdeo Pandit, a Sardar[42] of the Adil Shahi attacked and plundered Pune in 1631. He ploughed the land of Pune with an ass-driven plough as a symbol of misfortune for Pune (Gadgil, 1945, p.6). In addition, a severe drought prevailed in Pune during the years 1629-1630. The drought was extremely severe. Philosophers like Ramdas (1608-1681) have mentioned the severity of the drought (Kulkarni, 2008, p.77). He has mentioned that the severity of the famine was such that many farmers left their villages. Many of them died of starvation.[43] Due to both these human-made and natural calamities, Pune remained deserted for several years.

In 1636, Mohammad Adil Shah (1627-1656) granted Pune and the surrounding region to the Maratha Sardar Shahaji (1620-1664). Being a native, Shahaji started working towards the gradual development of Pune. He entrusted the responsibility of making Pune a habitable place to one of his senior assistants – Dadoji Konddev (Gadgil, 1945, p.7). The foremost challenge in front of him was to encourage people to resettle in Pune. He, therefore, gave a written royal assurance to the people of Pune that he would protect them from invasions (ibid). He took the necessary steps to ensure that people start cultivating their lands that were lying barren for several years. He did so by granting tax concessions to those who took up agriculture and

[42] Sardar was a title given to noblemen usually for their bravery in the battlefield.
[43] While describing the famine of 1629-1630, Ramdas writes,
बहूसाल कल्पांत लोकांसि आला महगें बहू धाडि केली जणाला
किती येक मृत्यासि ते योग्यस झाले किती येक ते देश त्यागुनि गेले
किती येक ग्रामे चि ते वोस जाली पिके सर्व धान्यें च नाना बुडाली (Apte, 1923, pp.23-24).

irrigation. Karve (1942, p.35) mentions that Dadoji Konddev had built a dam across the Ambil Odha –the stream flowing through Pune. It was due to Dadoji Konddev's initial efforts that Pune once again became a habitable place and an important administrative town.

By the mid-17th century, Shivaji (the son of Shahaji) aimed to end the rule of the Deccan Sultanates and establish Swarajya, i.e. self-rule and self-governance. He succeeded in fulfilling his aim, and most parts of Deccan came under his control. He worked towards the development of newer areas that came under his control. He undertook three main tasks for the development of new regions acquired within his territory: - 1) Bring non-arable land into cultivation, 2) Provide protection to villagers and their crops, and 3) Measure the land and fix revenue (Khobrekar, 2006, pp.555-556). Farmers who brought new land under cultivation were exempted from payment of revenue for initial years. In due course, the revenue gradually increased from 1/8th of the actual amount to the full amount. Those farmers who built check dams for diverting river water for agriculture purpose were given special concessions in the revenue. The revenue was fixed based on the inspection of the actual standing crop. He fixed 2/5th of the total production from every *bigha* [44] of land as the revenue. It was 40% of the total output which the farmers could pay in monetary form or as a portion of the agricultural produce itself (ibid, pp.567-572).

While encouraging the development of new areas, Shivaji had to prepare simultaneously for the occurrence of droughts and famines. He encouraged the construction of various kunds in temples for storing surface water. As hill forts once again gained importance for defence, Shivaji assured that the forts were well equipped with taakya and talav. He undertook the repair of several already existing taakya belonging to the Yadava period. His official orders known as *Adnyapatra* mention the precautions to be taken while building a new fort (Ghanekar, 2006, p.14). In it, he mentions that it is necessary to construct taakya and talavs on forts to store water for the entire period between two successive rainy seasons. He also advised his ministers not to rely on perennial springs because, during warfare, cannonballs fracture the rocks and water vanishes in the cracks. Instead, he encouraged them to have adequate water reserved on forts by building at least two to four taakya and talav (ibid). Accordingly, many forts built by Shivaji have talavs. The stone excavated for building talavs was utilised for securing the forts by building bastions (Kurkute, 2018, p.87). The talavs built by Shivaji are simple and devoid of any ornamentation. They do not have steps to access water. As Shivaji was in constant warfare with the Deccan Sultanate invaders, there were limited resources to build water structures (ibid).

Due to limited finance, Shivaji encouraged rich people and village heads to undertake irrigation works. However, historical records provide limited information about irrigation works carried out in Pune. Kulkarni (2008) and Jadhav (2008) both mention the construction of a check dam across the river Shivganga at Shivapur in Pune. Shivaji had created a mango orchard at

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[44] Ancient Indian unit for measuring area of a farmland. It is equivalent to 5/8th of an acre.

Shivapur. It needed to be watered, and hence, there was a need to build a bund across the river and bring water through the canal. Therefore, he threw up the challenge to the village heads of the region to build the dam and canal. A village head named Yesaji Kamthe from the village Kondhwe took up the challenge and built the bund and canal. Pleased with his efforts, Shivaji gifted him a land parcel at Kondhwe village (Jadhav, 2008, p.44-45; Kulkarni, 2008, p.41).

Thus, to summarise, Shivaji attempted to stabilise and develop Pune in the aftermaths of the Deccan Sultanate rule and the severe drought of 1629-1630. Shivaji's focus was to keep a check on the destruction caused by the Deccan Sultanates and establish self-governance. Therefore, one can observe a limited number of waterworks undertaken by Shivaji at an urban scale. Most of the work was concentrated on repairing the pre-existing talavs and cisterns, and building small canals for irrigation. Nevertheless, the idea of self-governance left a deep impact on the later Maratha rulers and especially Peshwe –the prime ministers of Shivaji. The Peshwe rulers continued his struggle to establish self-governance. They made Pune as their capital town in 1725. Peshwe Bajirao I (1720-1740) built a permanent residence for him known as Shaniwar Wada in 1732 A.D. (Sowani, 2017, p.56). Thereon, Pune developed from a small settlement of artisans into a medieval town. The following section discusses the water management works carried out by the Peshwe rulers and the way they transformed the landscape of Pune.

4.5. Nahar system of old Pune during Peshwe

4.5.1. Background

The old town of Pune experienced steady growth in the 18th century as Peshwa Bajirao I (1720-1740) made it the capital of Maratha realm in 1720 (Gadgil, 1945, p.10). While the exact population of Pune in the 18th century is unknown, Gokhale (1988, pp.40-41) estimates that the population of Pune during 1700-1750 may have been between 25,000 to 40,000. He estimates that Pune had to accommodate an additional floating population of around 30,000 on special occasions. It comprised mainly of *Brahmins*[45] who visited Pune during festivals like *Diwali* and *Dasara*[46] when the Peshwe distributed gifts and donations to them. On such occasions, the population of Pune would reach up to 100,000 (ibid). Gadgil (1945, p.19) estimates the population of Pune to be 150,000 during 1780. From the estimates of both Gokhale (1988) and Gadgil (1945), one can infer that the Peshwe needed to make a provision of water for 40,000 to 50,000 people who were permanent settlers and an equal number of people who visited Pune during festivals.

The three water streams Ambil Odha, Manik Nala, and Nagzari providing water to Pune were intermittent. Although they carried adequate water during the monsoon and winter months, they dried up during the summer months (Sowani, 2017, p.123). As such, they were unreliable

[45] The priestly caste in the Hindu religion.
[46] The two festivals are most celebrated Hindu festivals in India during the months of October-November.

sources of water during the summer months. Moreover, their water was unsuitable for drinking purpose. Therefore, the people of Pune had dug several wells near their houses to fetch water. The Gazetteer of Bombay Presidency (1885) mentions the presence of 1290 wells in Pune during the second half of the 19th century (GBP-XVIII, Part-III, 1885, p.326). Their number in the 18th century would vary. Nevertheless, the Gazetteer also mentions that most of the wells contained brackish (slightly salty) water. Therefore, people used their water for washing and bathing purpose but not for drinking purpose. Karve (1942, p.13) mentions that according to a survey done in the 1940s, Pune had 1511 wells. However, the survey also observed that only 86 out of the 1511 wells contained potable water. Based on the documentation of wells done by both the Gazetteer (1885) and Karve (1942), it seems clear that Pune had limited sources for obtaining drinking water. Besides, during years with deficient rainfall, it could have experienced a serious scarcity of drinking water.

Such a situation of water scarcity arose in the summer months of the year 1745 (Bhave, 1976, p.39). Common people had inadequate water as most of the public wells had dried up. However, some of the private wells of ministers and noblemen had adequate water, and they used it for watering their gardens. At that time, Peshwe Balaji Bajirao (1740-1761) was away from Pune. Therefore, his grandmother Radhabai ordered the noblemen and ministers to stop drawing the water from their wells for irrigating their gardens. Instead, she ordered them to make the water available for the use of common people (ibid).[47] This incidence indicates the willingness of Peshwe rulers in diverting excess water from the ruling class to the common people during times of natural disasters.

Nevertheless, after experiencing such severe water scarcity, Balaji Bajirao attempted to find a permanent solution to it. In 1749, he undertook the work of constructing two talavs at Katraj; a place located around 8 km to the south of Pune. From there, he laid an underground aqueduct system nearly 11 km in length that carried water up various public hauds in Pune and finally ended in his palace Shanivar Wada. This scheme was completed in the year 1755 and was popularly known as "Nahar-e-Katraj" (Sowani, 2017, p.124).

The Nahar-e-Katraj solved the water scarcity of Pune to a major extent. However, at the same time, Pune was expanding, and the Peshwe and noblemen belonging to their court were establishing new *peths* [48]. Consequently, by the end of the 18th century, three more nahars

[47] The original order given by Radhabai is in Marathi. It states, 'राजश्री त्रिंबकराव यांचे कारभारी आंम्हाजवळ बागेच्या मोटा चालवावयाची परवानगी मागत होते. त्यास आम्ही सांगितले की, बागेत केळी, ऊस, वांगीची झाडे व मीर शेंगांची झाडे आहेत. ती वाळली तरी कार्यास येतील. वरकड झाडे आहेत ती काही महिना दीड महिन्यात मारत नाहीत. तशाही मध्ये मरतीलच ऐशी असतील त्यांस नेहेमी दोन पाखाला लावून घालणे म्हणोन आज्ञा केली ते ऐकले नाही आणि सातारियास लिहून पाठवले, बहुत उत्तम केले! बाग बचावून शहर पाणिया वाचून हैराण करायचे हे तो कार्याचे नाही. (कारण) सरकारच्या पाखालादेखील (संगमावर) पाणियास जातात ऐसे आहे. नदीत पाणी नाही, याजकरिता हा बंदोबस्त आम्ही केला आहे. (पे.द. १८) (Bhave, 1976, pp.39-40).

[48] Peths were residential and business clusters within Pune. Usually every peth had a prominent business community in it. The head of a Peth was a *Shete Mahajan*. The Peshwe made a legal contract with him known as *watan-patra.* There were 18 peths in Pune established during times. The names of these peths are Kasba, Shanivar, Ravivar, Somvar, Budhvar, Shukravar, Guruvar, Nihal, Ganesh, Narayan, Bhavani, Muzzafarganj, Sadashiv, Ghorpade, Raste, Nana and Ganj (Gokhale, 1988, pp.16-17).

became operational in Pune for meeting the water requirement of these new peths (refer Figure 4.9).

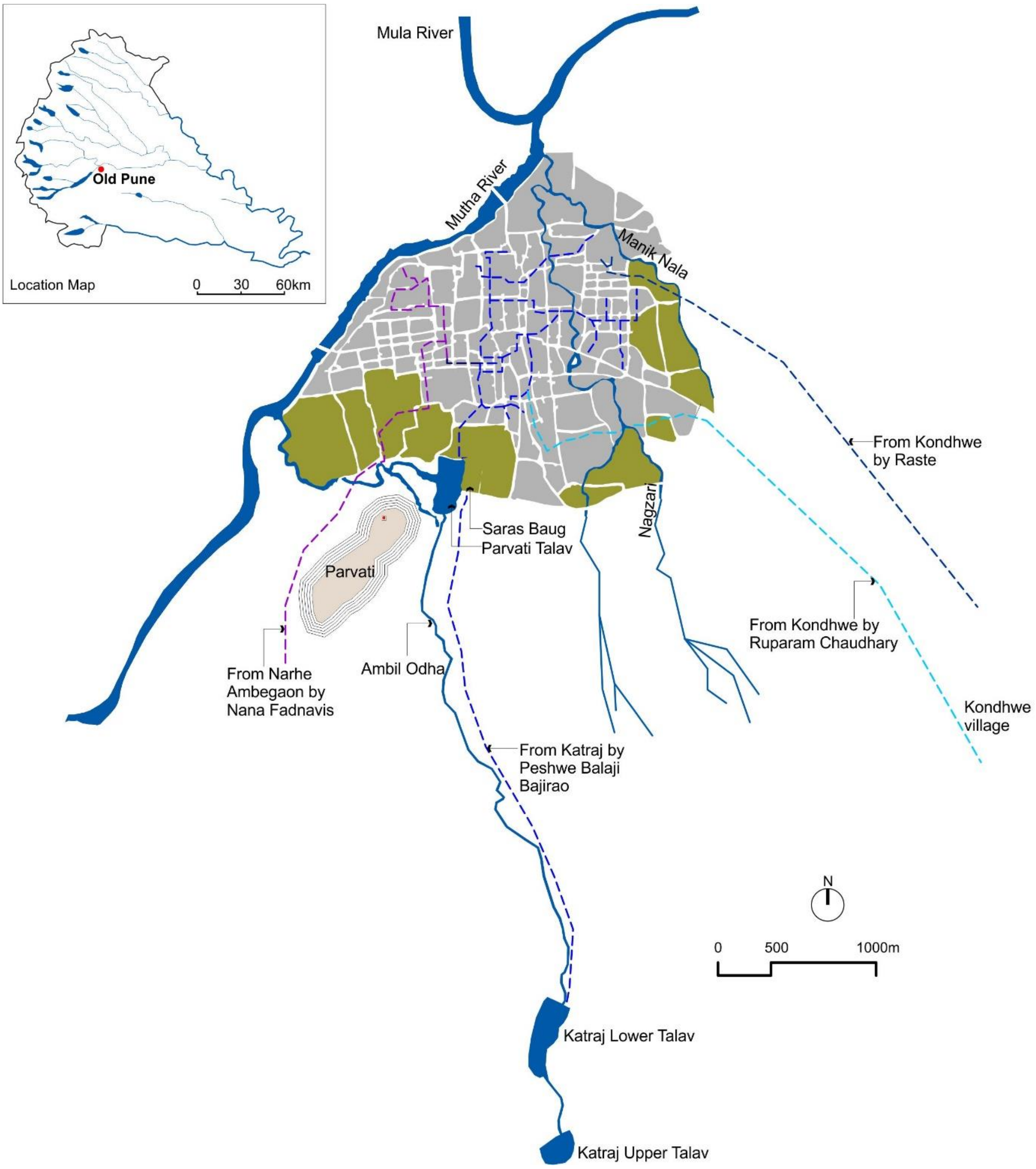


Figure 4.9: The nahars of Pune
Source: Adapted from Gokhale and Deo, 2016, p. 665.

In the year 1790, Nana Fadnavis laid a nahar. It brought water from Narhe Ambegaon located around 9.5 km towards the south of Pune. It fed four cisterns in Sadashiv Peth. Around the same time, Sardar Anandrao laid a nahar that brought water to Pune from the village Kondhwe located 11km to the southwest of Pune. It fed five cisterns. Ruparam Chaudhary also laid a nahar that brought water from village Kondhwe. It fed six cisterns. Therefore, by the end of the 18th century, there were four nahar operating in Pune (GBP-XVIII, Part-III, 1885, p.326). They supplied water to the different peths of Pune, as shown in Figure 4.8. From the figure, it can be seen that the spatial expanse of Katraj Nahar was larger compared to the other three nahars. Currently, no traces of the nahar systems can be seen except for the Katraj nahar. Due to these reasons, the Katraj nahar is explored here in detail.

4.5.2. Parts of the Katraj nahar

<u>Talavs at Katraj</u>

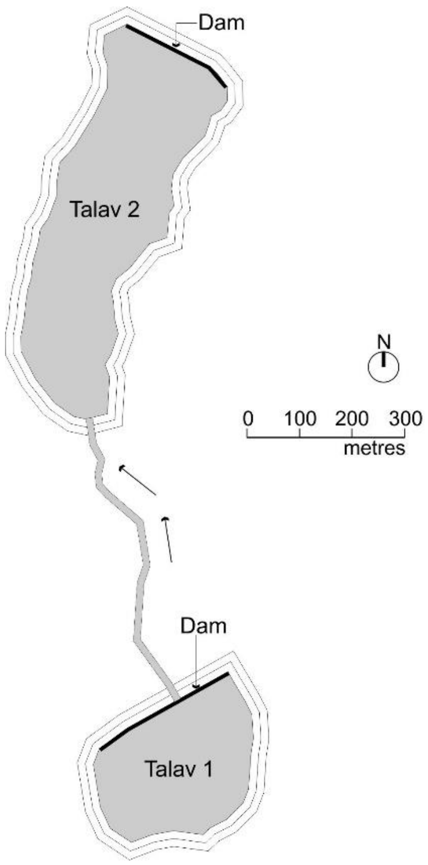


Figure 4.10: Sketch plan of Katraj Talavs.
Source: Data of field research carried on 25-11-2018 superimposed on Google Earth Pro 7.3.2.5491, 28-11-2018. Katraj Talav.

The area of Katraj is located on slightly higher ground with a gradual drop of about 100m up to the River Mutha (Gokhale and Deo, 2016, p.656). The surface water flowing down the hills was stored in an artificial talav by building a dam. Its wall was around 183m long, 9m high and 2.5m wide (Gokhale, 1914, p.3). It had holes closed with wooden plugs at specific locations. On removing the plugs, water from it would flow out. This released water was stopped once again by building another dam slightly below the level of the first one. The wall of this second dam was 300m long, 12m high and 3m wide (ibid). It had an opening at its bottom through which the water entered into the nahar. There was a reason for building two dams and creating two talavs one below the other. Often the streams carried a lot of mud along with them, especially during the monsoon. The first talav therefore functioned as a settlement tank allowing the mud to settle down. Once the mud settled down, relatively clean water could be released into the second talav. In addition, a provision was made to release the water of the first rainfall from the talav into the Ambil Odha flowing next to it. Besides, the overflow from the talav could be released into the Ambil Odha. Even from the second talav, water was first released into an ucchwas and then into the nahar. Any impurities, if present in the water, would accumulate in the ucchwas and people responsible for maintaining the nahar, would remove them periodically (Gokhale, 1914, p.11).

The nahar

The nahar was an arched masonry tunnel about 0.7m to 0.9m wide, about 1.8m high and nearly 6km to 8m long. The height of the tunnel was adequate for a person to walk comfortably (Gokhale and Deo, 2016, p.656). At specific locations, its height even increased up to 3m. As the nahar was cut to a considerable below the ground, it accessed many springs on its way (GBP-XXIII, 1884, p.327). At some places, water from nearby wells also passed into the nahar. At about every 30m interval, there were ucchwas to release air pressure.

Ucchwas

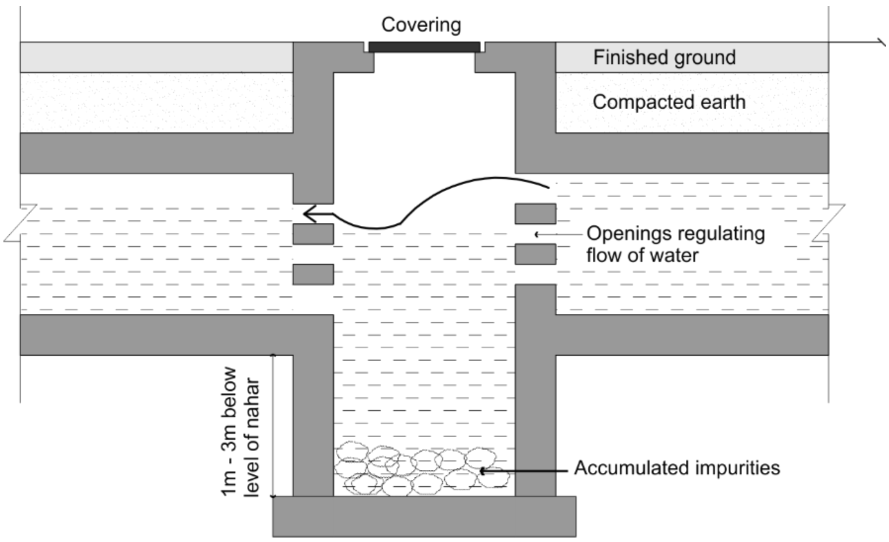


Figure 4.11: Sketch of Katraj Nahar Ucchwas.
Source: Adapted from Sowani, 2017, p126.

The ucchwas were sunk to a depth of 1.2 to 3m below the bottom of the nahar and were raised a little above the surface of the ground (Sowani, 2017, p.126). They acted as air shafts and settling chambers wherein the silt settled down at their bottom, and clean water flowed ahead. Every fourth or fifth ucchwas contained a masonry wall that controlled the flow of water. It had 7cm to 15cm holes through which water fell into the well. During repair or maintenance work, the flow of water could be stopped by inserting wooden plugs into the holes. Such a masonry wall was also present at branch junctions. At times, the flow of water through a particular branch could be stopped and allowed to pass through another junction. There were 125 such ucchwas within the 6 to 8km stretch of the nahar from Katraj to Shanivar Wada (Gokhale, 1914, p.5).

<u>Hauds</u>

The water from the aqueduct was stored in hauds. They were both public and private. People would collect water from the public hauds into their vessels and carry it to their houses. Private hauds were located within the houses of noblemen. According to Karve (1942, pp.14-15), there were 54 hauds connected to the Katraj aqueduct at different locations in the eastern part of Pune town. Out of these 54 hauds, 17 were privately owned by Peshwe ministers while the remaining 34 were public hauds (ibid).

Thus, the two talavs at Katraj, the nahar, ucchwas, and the hauds were the main technical components of the Katraj Nahar. However, as mentioned in the introduction, the nahar played a significant role in enhancing the landscape and image of Pune. This enhancement was possible due to the aesthetic vision of Balaji Bajirao who not only considered the utilitarian dimension of the Katraj nahar but also explored its aesthetical dimension through the design of the hauds, a fountain called Hajari Karanje connected to the nahar and the design of the Parvati Talav.

4.5.3. Hauds, fountains and talav

Hauds as public gathering places

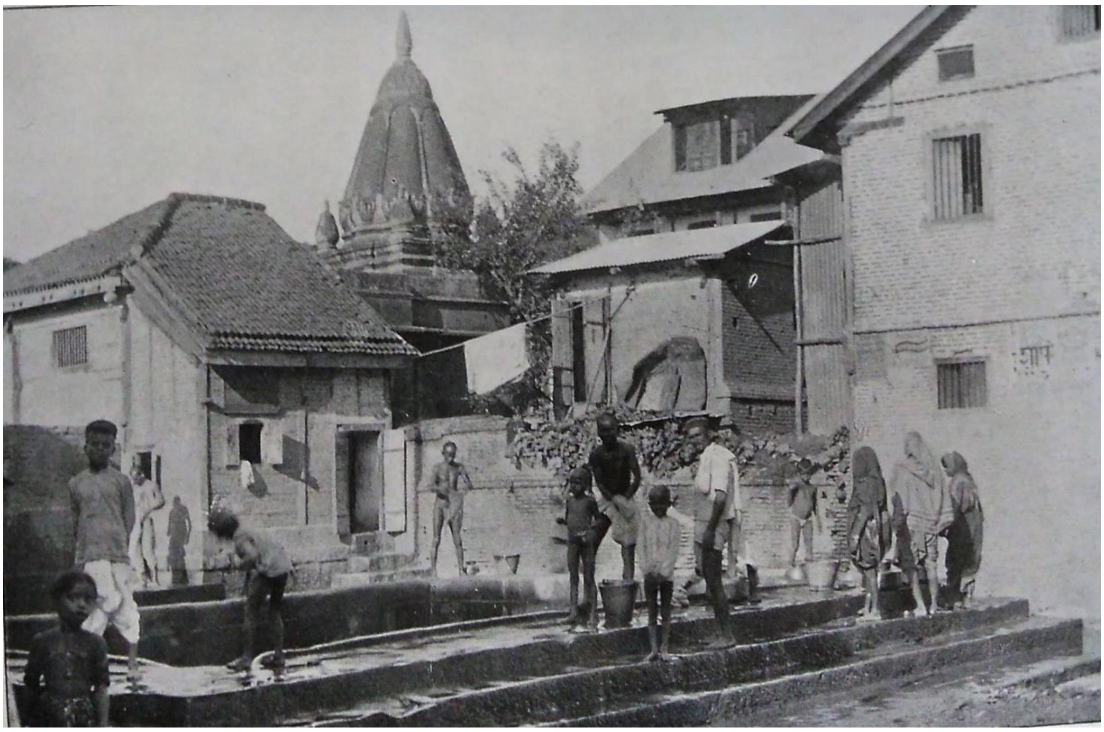


Figure 4.12: People gathered around one of the hauds in Pune.
Source: Elwin, 1907, p.15.

The peths had altogether about 100 hauds[49]. Each house within the peth had a haud within a radius of 50m (Gokhale, 2018, p.58). The space around the hauds was designed to function as a community space for public gatherings. People from the same community met at the hauds daily for fetching water and spent time with each other near water. Figure 4.12 shows the scene around one of the old hauds in Pune during the 1900s. Similarly, the Pushkarini haud outside Vishrambaug Wada was one such haud where people congregated daily for fetching water.

The Pushkarini Haud was built around 1790 along the southern side of the Peshwe Residence known as Vishrambaug Wada[50] (Sowani, 2017, p.200). The haud was about 15m long, 12m wide and 3m deep. It received water from the nahar built by Nana Fadnavis in 1790. The haud was an important landmark in the Sadashiv Peth of Pune. As seen in Figure 4.13, the haud nearly occupied 3/4th of the street width. Local residents gathered on the haud every morning for fetching water. Ample shade was provided by well-landscaped design that included flowering trees and creepers. The evenings saw local residents occupy the steps of the haud, utilising it as a public place. Thus, apart from its utilitarian function, the Pushkarini Haud served as a vibrant public place for people to congregate and interact with each other (ibid).

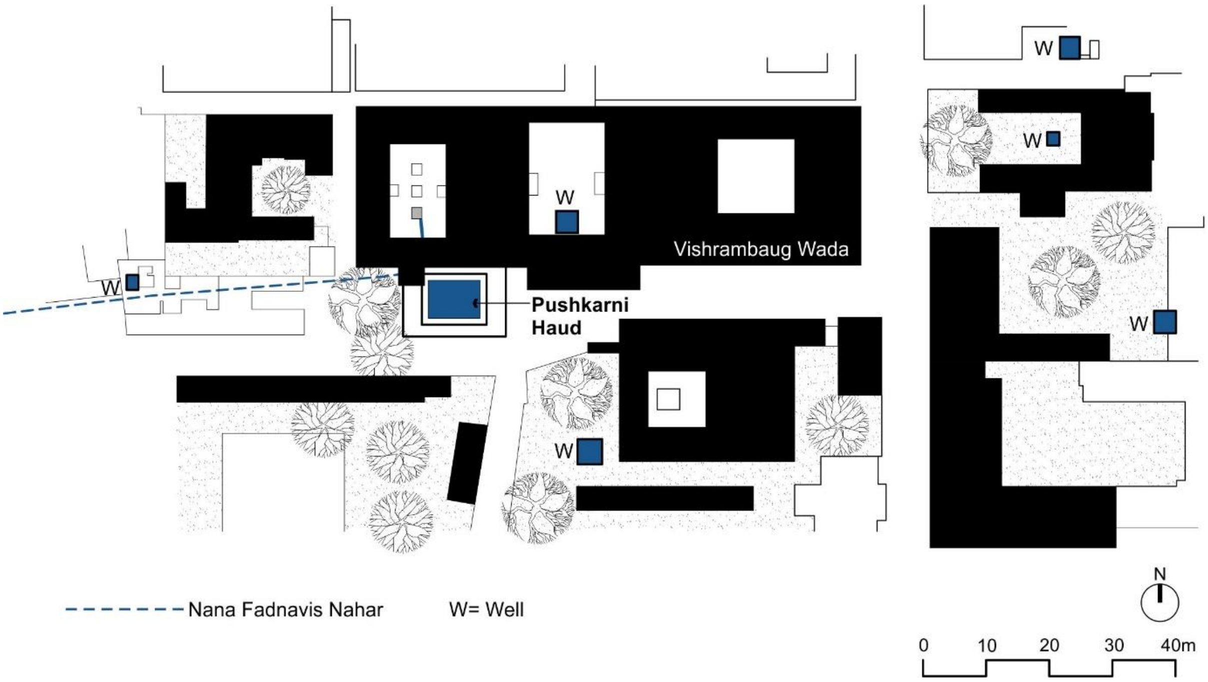


Figure 4.13: Plan of the area around Pushkarini Haud, Pune.
Source: Poona City Survey IOR/X/9864/24, 1876; Poona City Survey IOR/X/9864/30, 1876.

[49] The number of hauds mentioned in different sources vary. Karve (1942, pp.14-15) mentions 68 hauds, Gokhale (1914, p.8) mentions that the Katraj Nahar itself had 80 hauds, while Gokhale (2018) has mentioned the total number of hauds as 100. The number of hauds mentioned by Karve (1942) seem to be based on their survey done in 1942, when some of the hauds may have been destroyed. The number mentioned by Gokhale is based on the GIS mapping of hauds as marked on the Poona City Survey Maps (1876) and is more accurate. Therefore, it is reasonable to assume that there may have been about 100 hauds in total.

[50] Vishrambaug Wada was built by Peshwe Bajirao II (1796-1817) in 1807 A.D. (Joshi ,1868).

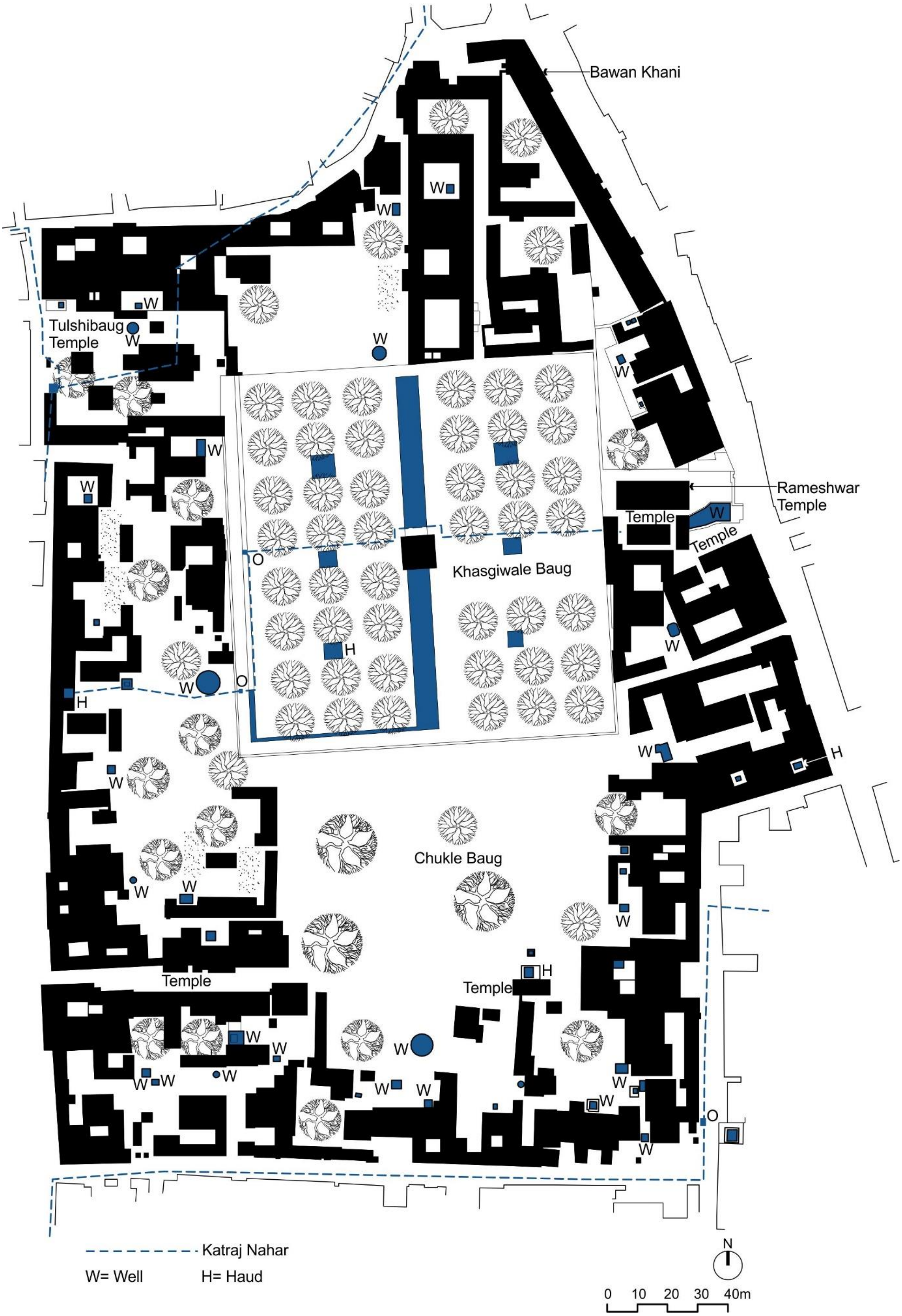


Figure 4.14: Plan of the area around Tulshibaug with wells, hauds and gardens. Source: Poona City Survey IOR/X/9864/29, 1877.

Similar to the Pushkarini Haud, the other hauds present within temple complexes and gardens added to the overall ambience of the place. The Tulshibaug Temple Complex is a good example of such a temple complex with two orchards within a dense peripheral urban fabric that functioned as a daily meeting place, especially for women. As seen in Figure 4.14, the Tulshibaug temple complex functioned as a big secured internal open space surrounded by residences along the periphery. There were several small and big temples amidst two orchards – the Khasgiwale Baug and Chukle Baug. Several wells and the water of the Katraj Nahar collected in the hauds watered the orchards. The open space contained several flowering trees and plants that added to its beauty.

Thus, it is interesting to observe the way hauds transcended beyond their utilitarian function and acted as landscape features and visual landmarks within the old settlement of Pune. Until the Peshwe rule, water structures had a religious and symbolic value. However, during the Peshwe rule, the water structures attained additional aesthetic value and became a landscape feature in gardens and open spaces.

Besides public hauds, the Peshwe had a few hauds and a fountain within their residence – the Shaniwar Wada. Although analysing these private water structures is not within the scope of the present research, it is worthwhile to mention in brief the Hajari Karanje (fountain with thousand spouts) which utilised water from the Katraj Nahar for aesthetic purpose.

Fountain: Hajari Karanje

Until the rule of the Peshwe, historical records do not mention the presence of any fountain in Pune. Peshwe Madhavrao II (1796) was the first one to have built the Hajari Karanje at Shanivar Wada, the residence of the Peshwe. The fountain is located towards the west of the Wada, as shown in the figure. A branch of the Katraj nahar supplied water to it. Parasnis (1921) has described the Hajari Karanje, which was a piece of attraction for the guests who visited the court of Peshwe Madhavrao II. He says,

[Hajari Karanje] had the shape of a lotus flower of sixteen petals – each petal having sixteen spouts with a circumference of 80 feet. It is said that in India there is not a single fountain like this anywhere having 196 jets, not even in Europe, excepting the celebrated fountain 'Fountana di Trevi' at Rome. The water of this great fountain played a hundred patterns while the sun for its amusement would make and break a thousand rainbows. (Parasnis, 1921, p.17).

The Hajari Karanje is probably the only fountain which the Peshwe built. Historical records do not mention any other fountains before and during the Peshwe rule in Pune. Besides, the hauds and Hajari Karanje, Peshwe Balaji Bajirao built a beautiful talav towards the south of Pune at the foot of Parvati Hill.[51] It is an interesting example of a multi-functional water storage structure serving several purposes.

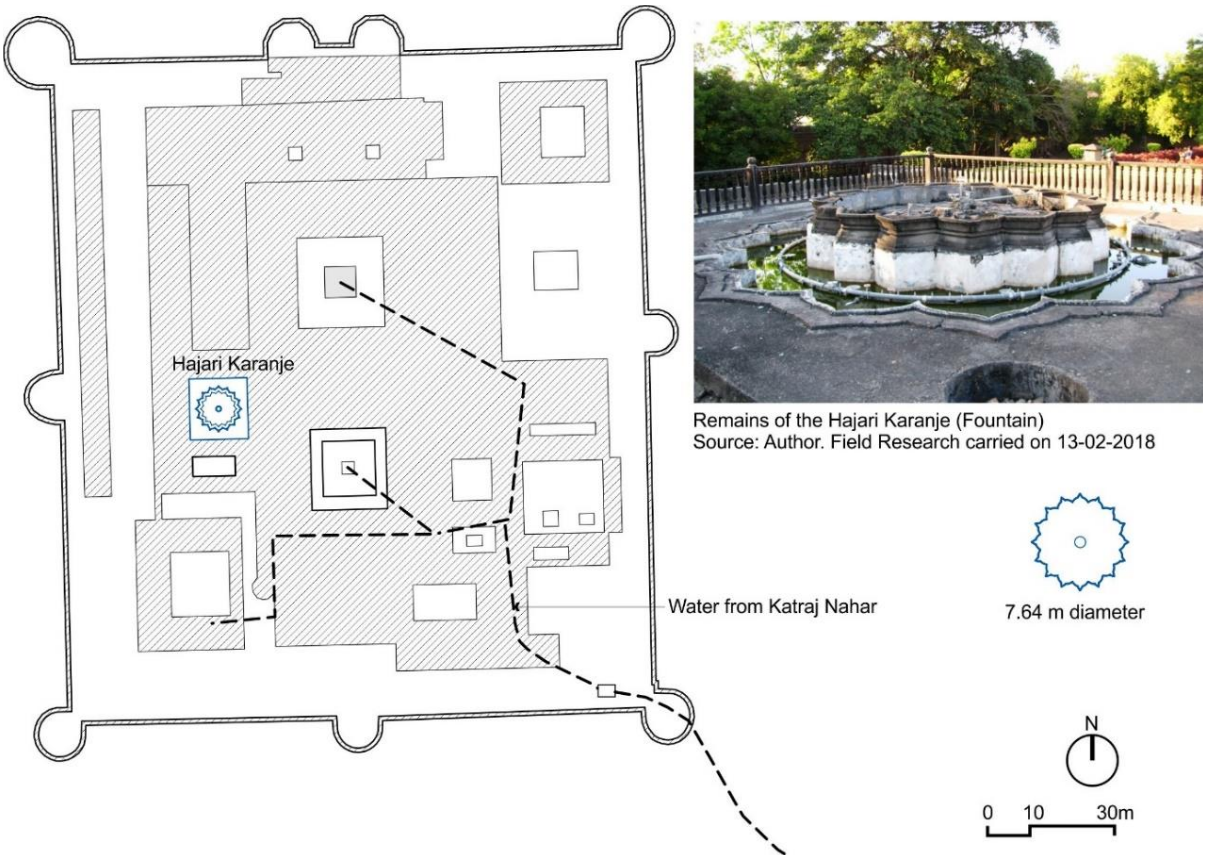


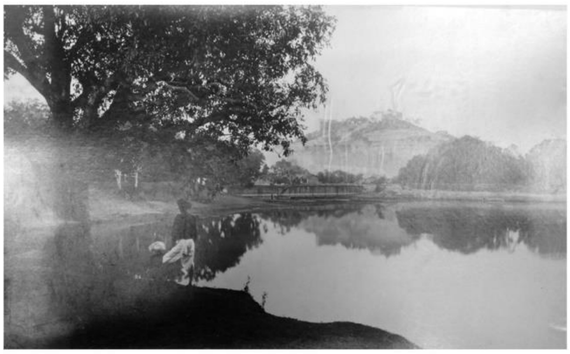
Figure 4.15: Plan of Shanivar Wada showing Hajari Karanje.
Source: Adapted from Poona City Survey IOR/X/9864/22, 1876; Sowani, 2017.

Parvati Talav

While the nahar was being laid, the stream Ambil Odha flowed through the city in the south-north direction. The nahar was laid along its eastern bank. During the monsoon of 1752, it flooded, and about 50 people staying nearby were washed away in flood (Sowani, 2017, p.120) Taking serious cognisance of this accident, Balaji Bajirao decided to divert the flow of the odha. He ordered his masons to build a 25-acre talav at the foot of Parvati during 1753-1755 A.D (Sowani, 2017, p.108). The talav became an equally important component of the Nahar System. It served varied purposes. Firstly, it diverted the flow of the Ambil Odha, so that it would flows away from the main city. Its diversion prevented further human loss in floods during the monsoon. Secondly, the talav allowed to have buffer storage of water in case the water supply from the Katraj talavs fell short. A provision was made to allow water from the talav to enter into the nahar. Similarly, any excess water from the nahar entered into the talav. Thirdly, having a talav close to the town helped to recharge the falling groundwater table

[51] Parvati hillock is located to the south of old Pune that rises to a height of about 100 m. It is famous for the Shiva Temple located on the hilltop (GBP-XVIII, Part-III, 1885, p.386).

within its vicinity. In a few years, the level of groundwater in the adjoining wells increased. Lastly, the large quantity of stone that was excavated while creating the talav could be utilised for building wadas and other structures (ibid).



View of Parvati Lake
Source: [Photograph] 866/3(35), British Library, London.

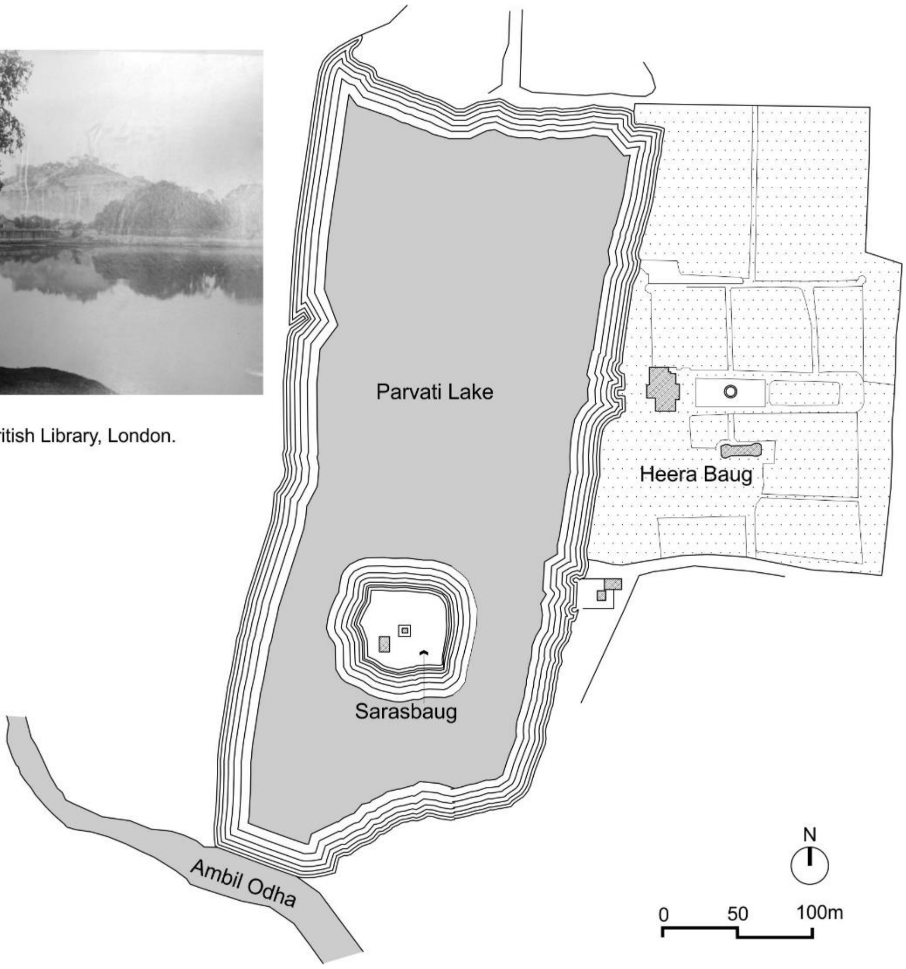


Figure 4.16: Plan of Parvati Talav.
Source: Adapted from Poona City Survey IOR/X/9864/34, 1876.

During the construction of the talav, Balaji Bajirao imagined a beautiful garden in the middle of the talav. Accordingly, an island was kept in the middle of the talav, and a beautiful garden was created popularly known as the Sarasbaug. In 1784, Peshwe Madhavrao II commissioned artisans to build a Ganesh temple in the garden, as the Peshwe were disciples of Ganesh. A garden called the Hirabaug was also built next to the talav. The entire space around the talav became scenic (Sowani, p.109).

Thus, the utilitarian components of the Katraj nahar were treated aesthetically so that they become important landmarks in the landscape of Pune. The nahars were the first instances of a full-fledged urban water infrastructure system in Pune. However, the Peshwe gave equal importance to the development of water systems in the villages around Pune, which indicates their effort at maintaining the urban-rural balance. Three examples of village water supply systems are discussed in the following section.

4.6. Talavs and kunds built by the Peshwe

The Peshwe and their ministers undertook the construction of many talavs and kunds in the villages of Pune. The talavs stored rainwater and surface runoff required for domestic purposes. Most of them fulfilled the water requirement of one or more villages. The purpose of kunds remained the same as those of baravs. Most of them were within a temple complex, where devotees bathed before entering the temple. Additionally, the kunds discussed in this section were also used for irrigation purpose. Influence from the nahars is seen in the design of talavs and kunds. Both the types had a provision for carrying water up to the settlement. Some of the talavs such as the Holkar Talav and the kunds at Ranje were sources of water for the nahars that carried water up to the settlement. The following section discusses some examples of talavs and kunds.

4.6.1. Mastani Talav at Vadaki

Vadaki is a small village about 20km to the south-east of Pune. Bajirao I is believed to have commissioned workers to build the Mastani talav[52] at Vadaki. The village of Vadaki lies at the foot of the hilly pass called the *Dive Ghat*. It was a major thoroughfare connecting Pune to some of the towns and villages located towards its south-west. Therefore, in 1740, Bajirao I ordered the construction of the Mastani Talav for fulfilling the water requirement of the travellers along the route. (Peshwe Daftar, 30-03-1740; Sowani, 29-01-2019). It seems from the location of the talav that the people who constructed the talav chose the site strategically. The talav lies in a shallow terrain surrounded by hills on its northern, eastern and southern sides (refer Figure 4.17). As a result, it collected the surface water flowing down the hill slopes. People then utilised the stored water for irrigation and household purposes.

The surface area of the talav is about 6ha. A letter dated 30th March 1740 mentions the water accumulated in the tank after the first showers of the rainy season. It mentions the north-south and east-west extent of the accumulated water to be 500 hands each (about 230m) and the depth of the water varying between 4.5m to 6.5m. It can be inferred, based on these figures, that the talav could have stored about 238,050 to 343,850 cu.m of water (ibid).[53] Thus, the

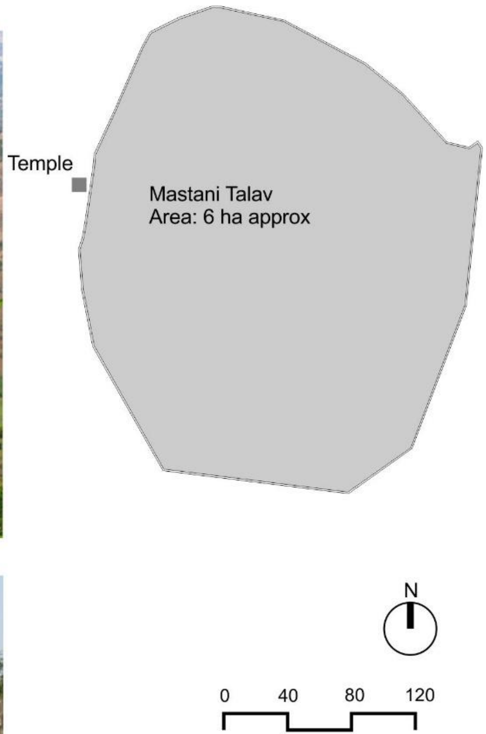
[52] The original name of the talav is unknown. Mastani, the princess of Bundelkhand was the second wife of Bajirao Peshwe. A legend says that Bajirao had built a palace for her near this talav and hence people called the talav as Mastani Talav after her name. However, historical sources do not specify the name of the talav as Mastani Talav.

[53] The original letter in Marathi Modi script says, ...पहिले पुर्वाचे नक्षत्राचे पाणी लांबी उत्तर दक्षिण तिही बुरुजांमध्ये सुमार १०० हात व रुंदी पूर्व पश्चम असी नवद व खोली कोठे तीन हात कोठे चार हात येणेप्रमाणे होते पुढे उतराचे दोन तीन पाऊस बरेच पडले त्याचे पाणी पहिल्यासुधा लांबी उतर दक्षण हात सुमारे ५०० हात व रुंदी पूर्व पश्चम हात ५०० व खोली पहिली चार हात व हालीची १० हात येकूण तेरा चवदा हात पश्चमेचे आंगे पके इमारतीकडे आहे (पाणी) कोठे अधिक उणे जसा चढ आहे तसे आहे व आणखीही वरचेवर येतच आहे पावसाचेही येते पूर्वेकडील दोही काऱ्यातील वोढे व दक्षिणेकडील तल्याचे पालीबाहेरचे वोढे जिले वाहो लागले ते खणोन बांधोन तल्यात आणिले

storage capacity of the Mastani Talav was enormous, which could have easily fulfilled the water requirement of Vadaki.

A two-metre wide masonry retaining wall secures the edge of the talav. Within the thickness of the wall, there is a flight of steps leading to the level of the stored water. Another flight of steps leads to a 1.2 m wide platform located about 3.2m below the top level of the retaining wall. From the field observation, it seems that people used this platform for lifting water from the talav. Behind the platform is a small cell containing the deity of Shiva as a guardian for the talav.

View of Mastani Talav from Dive Ghat



Temple located near the edge of retaining wall of the Mastani Tank

Figure 4.17: Plan and photographs of Mastani Talav, Vadaki.
Source: Data of field research carried on 22-11-2018 superimposed on Google Earth Pro 7.3.2.5491, 05-04-2018. Mastani Talav.

आहेत..बागेतील झाडे कुल जगली आंबराईही पावसाचे पाण्याने कुल नवी फूट जाहाली. (Peshwe Daftar, 30-03-1740, pp.25-26. Source emailed by Sowani on 29-01-2019).

The Mastani Talav is one of the early examples of talavs built by the Peshwe. Later, the Peshwe rulers and some of their ministers such as the Holkars patronised the construction of several other water structures in the state of Maharashtra and India. Ahilyadevi Holkar (1767-1795)[54] is well known for patronising several waterworks all over India. She provided the necessary financial support for constructing water structures at Kedarnath, Varanasi, Nashik, Niphad, Dindori, Satara, Chandwad, and many other places (Sonawane, 2018, p.125). The next section describes two such talavs built by the Peshwe and Holkars at Jejuri in Pune.

4.6.2. Peshwe and Holkar Talavs at Jejuri

Jejuri is a pilgrimage town located about 50km to the south-east of Pune. It is famous for the temple of Khandoba located on a 75m high plateau towards the west of the old village (GBP-XVIII, Part-III, 1885, p.133). Many pilgrims visit the temple on special occasions and festivals that happen three to four times a year.

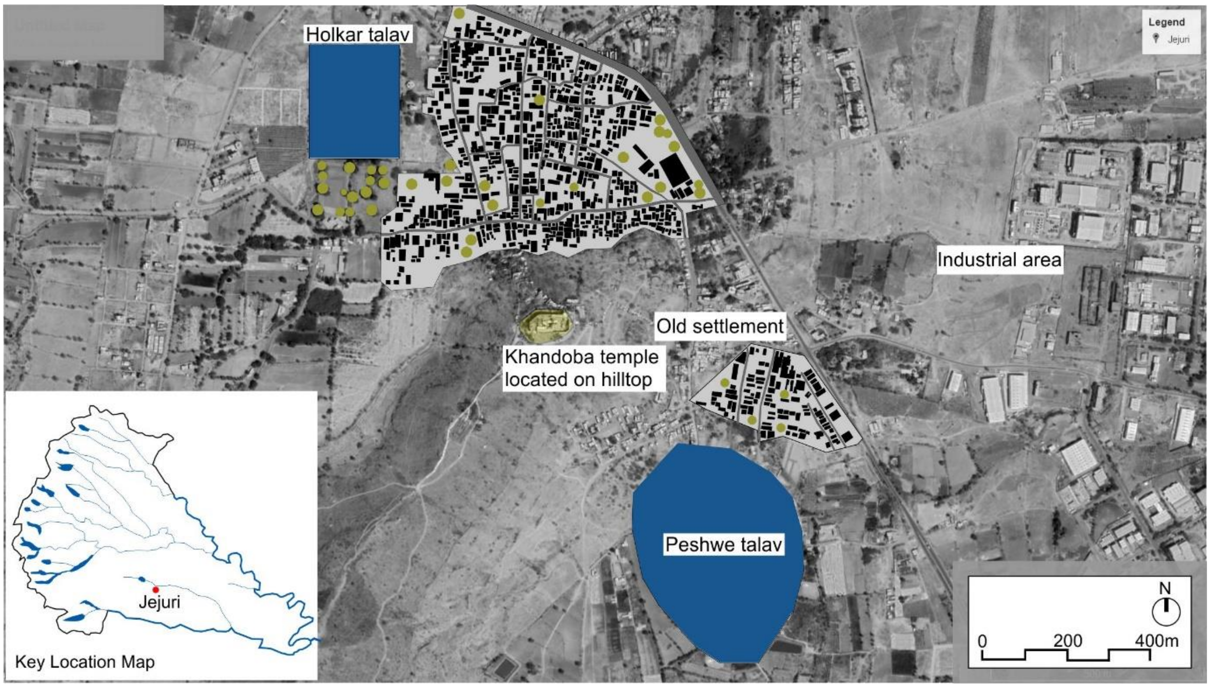


Figure 4.18: Map showing the Peshwe and Holkar talavs of Jejuri.
Source: Adapted from Kamble (2018); superimposed on Google Earth Pro 7.3.2.5491, 04-02-2017. Jejuri.

Peshwe Bajirao II built a talav to the south of the old town for meeting the water requirement of the pilgrims visiting Jejuri. It has an oval shape and an area of 15 ha approximately. Similar to the Mastani talav at Vadaki, it stores rainwater as well as surface water that flows down from the slopes of the plateau. A two-metre thick masonry wall encircles the talav. People could access the water by a flight of steps located on the eastern side of the talav. People used its water primarily for irrigation purpose. Besides irrigation, people and the pilgrims who visited

[54] Ahilyadevi Holkar administered the state of Indore from 1767 A.D. to 1795. She is considered one the few able and just women administrators in India (Sonawane, 2018, p.125).

Jejuri used its water for the bathing purpose. The soakage from the tank fed a well, known as the Malhar Tirth. Pilgrims bathe in it as part of the religious ceremonies (GBP-XVIII, Part-III, 1885, p.133).


Peshwe Talav with the Khandoba temple on hill behind

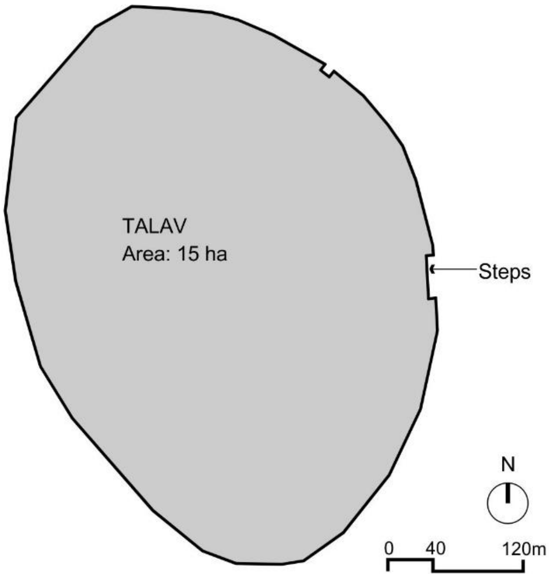


Figure 4.19: Plan and photograph of Peshwe Talav, Jejuri.
Source: Data of field research carried on 23-11-2018 checked with Google Earth Pro 7.3.2.5491, 16-02-2017. Peshwe Talav.


Holkar lake with Khandoba temple on hill behind


Flight of steps

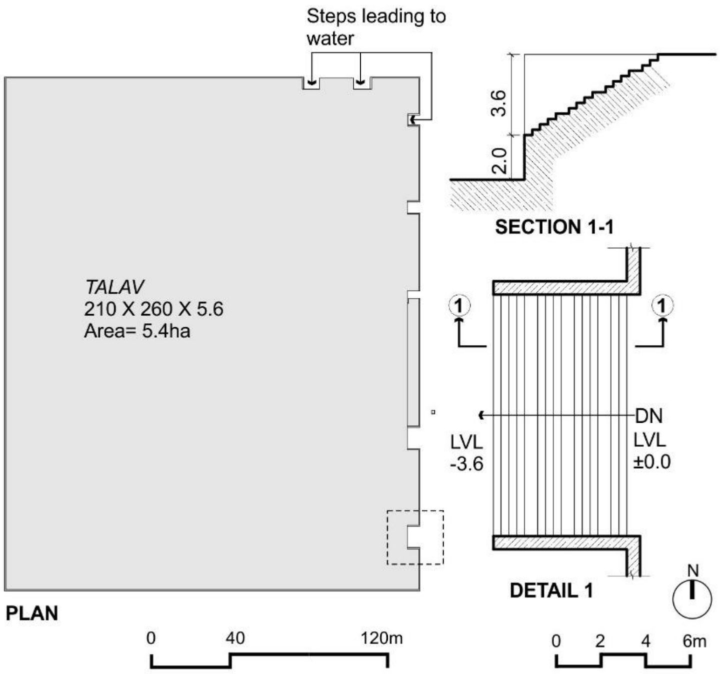


Figure 4.20: Plan, section and photographs of Holkar Talav, Jejuri.
Source: Author. Field Research carried on 23-11-2018.

In the year 1770, Tukoji Holkar built another talav to the north-west of the old village. It is a rectangle measuring 210m x 260m, having a depth of about 5.6m (see figure 4.20). It is protected by a masonry retaining wall. It feeds two square wells with sides 4.4m and 1.6m located along the northern and eastern side of the tank. The talav is located on a higher level than the village. Water from the talav was circulated in Jejuri through nahars by using the natural gradient of the terrain. These channels fed some of the hauds such as the Janubai Haud, Maruti Mandir Haud, Barbhai Haud and so on. Presently, these hauds do not exist. However, the people of Jejuri were once dependent on their water supply.[55]

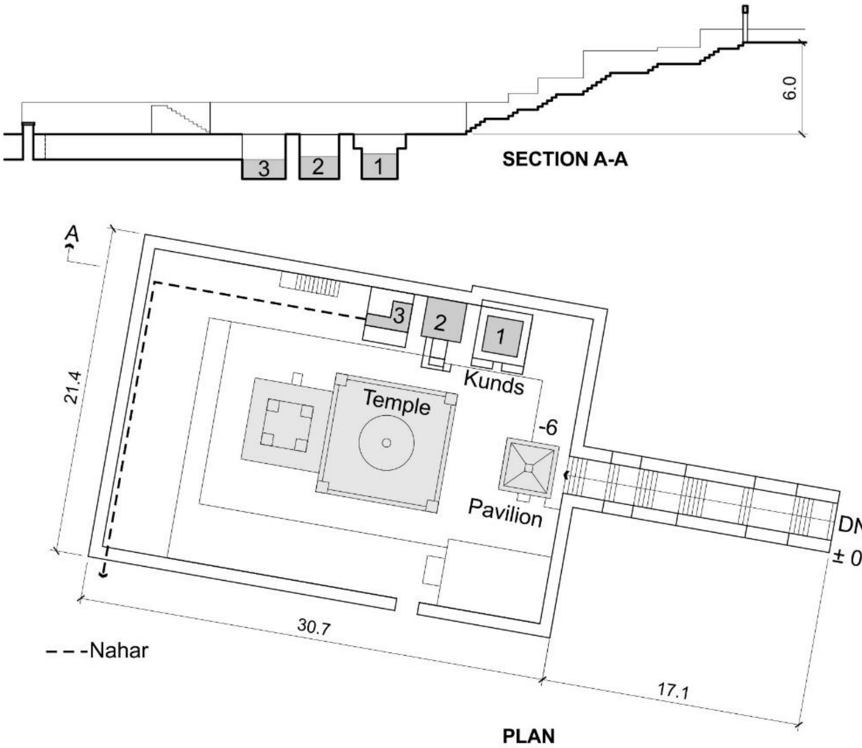
Thus, it can be concurred that talavs functioned as critical structures storing rainwater as well as surface-runoff from the adjacent hills. Their storage capacity was enough to fulfil the water requirement of the entire village. As highlighted earlier, each of the three exemplified talavs possessed varying storage capacities, namely Mastani Talav (about 300,000 m^3), Peshwe Talav (600,000m^3) and Holkar Talav (200,000 m^3). Considering their storage capacities, one may infer that they could have easily made the villages of Vadaki and Jejuri self-sufficient in terms of their water requirement. Besides talavs, the Peshwe supported the construction of several temples that had kunds within their vicinity for storing groundwater. The following section discusses three kunds found within the Ranjeshwar temple complex at Ranje.

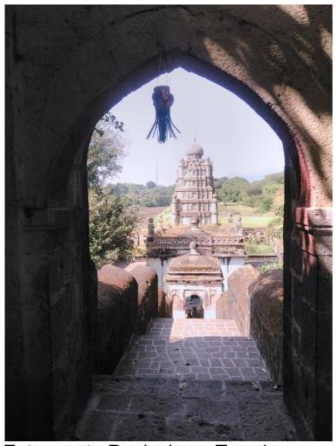
4.6.3. Kunds at Ranje village

Figure 4.21: Map of Ranje showing the location of kunds.
Source: Data of field research carried on 25-11-2018 superimposed on Google Earth Pro 7.3.2.5491, 04-02-2017). Ranje.

[55] During field research, it was observed that the old people of Jejuri had themselves used the water from the hauds present within the settlement. While, no one could tell the precise year when the nahar stopped functioning, many people said that the hauds were present until the 1990s.

Ranje village is located at a distance of about 28km to the south of Pune. The Ranjeshwar temple is located about 60 to 70m away towards the west of Ranje settlement at a lower level. There exists a drop of about 6m from the village up to the temple, which stands within agricultural fields. The temple premises is rectangular in plan measuring 31m x 21m with an area of 650 sq.m approximately. Towards the north-east of the temple premises, there are three kunds of water. Their strategic location safeguards them from direct exposure to sunlight.[56]





Entrance to Ranjeshwar Temple

Figure 4.22: Plan, section and photograph of Ranjeshwar temple.
Source: Author. Field Research carried on 25-11-2018.

The three kunds are next to each other. As shown in Figures 4.22 and 4.23, the first kund is a 2.4m wide square having a depth of 2m, known as the Dev kund. Water enters into it through a natural spring present at its bottom. Since the water from the spring is pure water, people use it for drinking purpose. The four sides of the kund have four niches that once had deities inside them.[57] Their presence added to the sanctity of the place and reminded people that they are obliged to take care of their water. The overflow of water from the first kund gets collected into the second kund through a spout having the form of a cow's mouth. The second kund is a 2.6m wide square with a depth of 1.4m. People used its water for bathing purpose. The

[56] During the field research it was observed that the shadow of the Ranjeshwar temple cut of direct sunlight and the kunds remained in shade for most time of the day. Besides the presence of trees with dense foliage around the temple complex also kept the kunds in shade.
[57] No details about the type of deities present in the niches could be obtained during the field research.

overflow of water from the second kund was collected into the third kund, which is a rectangle with sides 1.7m x 2.0m and depth of about 1.2m. Villagers used its water for washing their clothes and utensils. From here, a nahar carries the excess water to the agricultural fields on the rear side of the temple.

The system of kunds exhibits a creative approach to water management. It ensures that water is utilised without any wastage. Moreover, through its design, it sets a priority for utilising the available water. Firstly, for drinking; then for bathing; then for washing; and lastly for agriculture. The architectural detailing of the kunds is noteworthy. The protective edge of the kunds is raised by 10 cm from the adjacent ground level. This level difference prevents the entry of surface-runoff from the surroundings into the kunds and prevents the pollution of their water.[58]

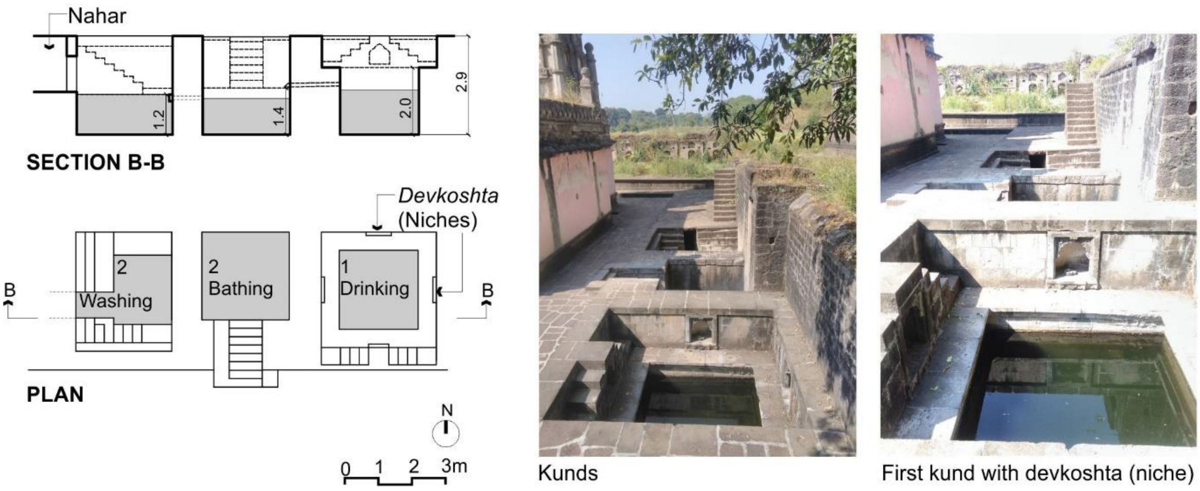


Figure 4.23: Plan, section and photograph of kunds at Ranjeshwar temple, Ranje.
Source: Author. Field Research carried on 25-11-2018.

Although designed during the Peshwe period after the nahar system, the kunds continue to carry the features of the barav as seen in the early medieval period. Their walls contain niches which once had images of Hindu deities inside them. However, one significant difference is noticed in the niches of earlier kunds and the ones found here. The niches of earlier kunds had stone lintels as spanning members above them. While the ones found here have arches. The main reason for this lies in the difference of construction techniques during Hindu and Deccan Sultanate Period. The Hindu construction technique was trabeated while the Deccan Sultanates introduced the arcuated construction technique in the Deccan Region. As a result, the kunds at Ranje are a fusion of two construction techniques. However, the idea of water being a sacred element still prevailed during this period. Along with water storage, the flow of water gained equal importance.

[58] Based on field research carried on 25-11-2018.

4.6.4. Conclusion

This chapter aimed to understand the influence of Persian technology on the design of nahars, talavs and kunds, and their contribution to the development of settlements and bringing about a change in the landscape of Pune. The discussion so far suggests that firstly these water structures mark the beginning of an infrastructure system that was critical for the spatial development of the settlement. Secondly, the integration of these systems within the settlement fabric brought about a change in the landscape of Pune with water structures and orchards becoming a part of the built environment. These two transformations are discussed in further detail.

The beginning of water infrastructure and its criticality in the development of settlement

Until the period of the Deccan Sultanates, we mostly observe individual stand-alone water structures storing rainwater and groundwater. Due to the limited expanse of settlements, the idea of conveying their water up to the settlement was yet to develop. People did convey water through water channels, but only for irrigation purpose. However, as settlements gradually started developing into towns in the medieval period, the Deccan Sultanates thought about conveying water to settlements and introduced the nahar system. From thereon, we see that water structures start becoming complex, forming a system and do not remain mere individual structures. For instance, the nahar is a system consisting of water storage media (bavdis or talavs), conveyance media (nahars) and storage media (hauds) interconnected to each other. Besides, the ucchwas are also essential components for the smooth flow and maintenance of nahars. The Persian technology of nahars influenced the design of talavs and kunds also. Earlier these were mere storage structures, but now we observe that they also have provision for conveying water. Thus, we see that Deccan Sultanates, Maratha and Peshwe rulers gave special attention to the flow of water in addition to storage.

The nahars, talavs and kunds become critical infrastructure systems in many ways. Firstly, they were critical for the spatial expansion of Pune, as seen in Figure 4.24. The new peths established by Peshwe rulers rarely had potable clean water. As a result, bringing water from outside through nahars became critical for the development of these new peths in Pune. The observations reveal that Pune's development during the Peshwe Period was primarily due to the availability of clean water from nahars. Similarly, the talavs at Jejuri were critical for fulfilling the water requirement of the pilgrims and at the same time protecting the settlement from the excessive surface-runoff from the adjoining hills.

Secondly, the nahars and kunds were critical as they created power relations. The rulers and common people shared a hydraulic relationship with each other. As the common people had limited financial resources to build the water systems, they depended on the patronage of the rulers. Similarly, building water systems was necessary for the rulers as they received taxes in return. Thus, there was a mutual dependency. Lastly, this dependency was also amongst common people, as these water systems became shared public places.

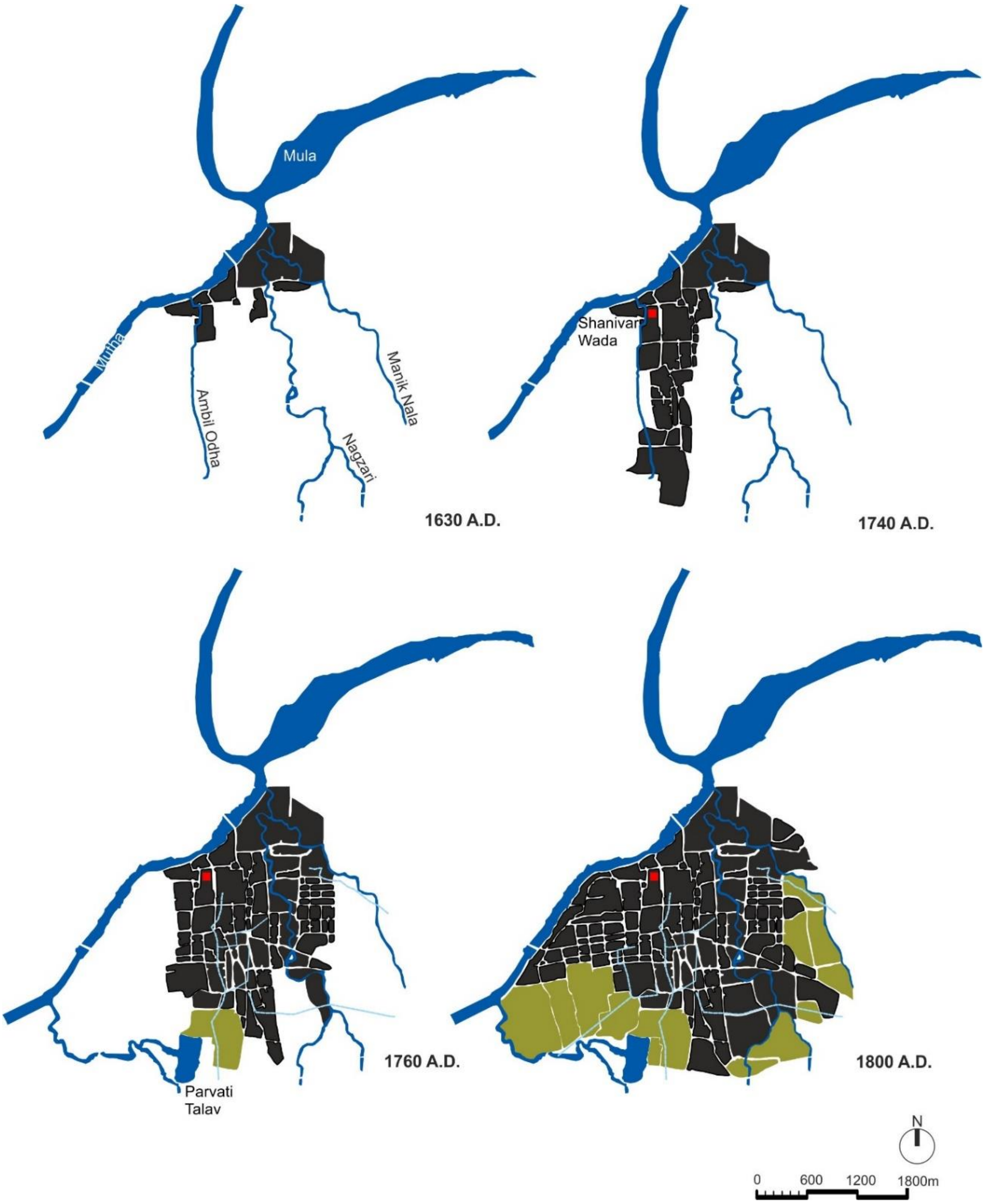


Figure 4.24: Development of Pune from 1630-1800 A.D.
Source: Adapted from GBP-XVIII, Part-III, 1885, p.266; Diddee and Gupta, 2013, p.62.

The criticality also emerges from the providers (i.e. the ruling class) having the foresight to understand the development of a technical artefact into a socio-technically configured space. The water infrastructure transcends its technical brief and configures a more complex socio-spatial infrastructure network. It does not arise so much from the notion of failure of these systems. It seems that the rulers and people were prepared for the possibility of their failure. As discussed earlier, people always had a backup arrangement for obtaining water, in case the nahars failed to supply the required quantity of water. One arrangement was to utilise water from their wells, and upon its inadequacy, the Parvati Talav functioned as a backup reservoir.

In summation, we can conclude that the nahars, talavs and kunds are the first evidences of critical infrastructure in Pune. These systems were critical for the development of Pune and the maintenance of the social relations shared over water. These systems were not only responsible for the spatial growth of Pune alone, but also for its environmental and resource-sensitive development.

Nahars and the landscape of Pune

Until the 14th century, people had perceived water as a valuable natural element. There was deep reverence for water in society that reflected through the water storage structures. During the rule of the Deccan Sultanates, the Persian technology of constructing nahars allowed the movement of water for the first time. With moving water, people started gradually exploring its aesthetic qualities, its playfulness and use in landscaping.

As observed in the case of Tulshibaug temple complex, along with water being a sacred element, it also became a landscape element watering the orchards and gardens within the complex. The availability of plenty of water enabled people to have fruit orchards and gardens. During the Peshwe Rule, there were at least 13 gardens in Pune (Talwalkar, 1936, p.70; Gokhale, 1988, p.42). Sarasbaug, Hirabaug Tulshibaug, Natu Baug, Manik Baug, Bhide Baug, Belbaug, and Ramana are the names of some of the gardens. Similarly, one can see water fountains such as the Hajari Karanje for the first time in Pune during the Peshwe rule. Furthermore, water structures such as hauds themselves became landscape elements and reference points in settlement of Pune. The Pushkarini Haud was a place for gathering and interaction for people in the morning and evening. Similarly, people gathered daily on several other hauds in Pune for fetching water, bathing and performing rituals. People named many streets and *chowks* (street squares) after the hauds present there. For instance, Kala Haud, Badami Haud, Bahulicha Haud, Phadke Haud and so on continue to be the chowk names in Pune until today.

Thus, we may conclude that with the abundant availability of water, orchards and gardens became a part of the settlement. More importantly, water infrastructure in the form of hauds was integrated into the settlement fabric of Pune, leading to its development from a small settlement with few houses into a beautiful medieval town.

However, the growth and prosperity of Pune in the 18th century was short-lived. By the beginning of the 19th century, it was destroyed due to the internal rivalry between the Maratha sardars. Sooner, Pune fell to the hands of the British Empire in 1817. Since the British came from an entirely different context; they possessed different ideas about water management. Their perception of water had a major impact on water management practices in the following years. The next chapter discusses the British Colonial impact on water management practices in India.

5. Productive waterworks: Dams, canals, and piped water network

This chapter investigates the state of Traditional Water Infrastructure (TWI) during the British Colonial (1817-1947) and Post-Colonial (1947 onwards) periods against the background of newly emerging water management policies. The observations show that there was a gradual decline in TWI and a simultaneous increase in the number of large dams, canals and tubewells during the colonial and post-colonial periods. In identifies that lack of patronage, interference in the traditional socio-cultural practices of people, tendency to find quick-fix solutions to increasing water demand during rapid demographic and spatial expansion of Pune were the main reasons for the decline of TWI.

5.1. Introduction

In the early and late medieval periods, there was a deep reverence for water in the society due to its limited availability as observed in the previous chapters. The water infrastructure developed during these periods reflected this reverence. The water structures built by the Hindu and Deccan Sultanate rulers were not mere utilitarian structures. They had cultural and aesthetic value. In the 19th century, there was a discontinuity in the traditional approach of constructing water infrastructure during the British Rule. The British coming from a different physical and cultural context and more importantly, undergoing the industrial revolution had different understandings of water and water management.

Back in England, the peculiar characteristics of its rivers to have perennial water supply, steady flow and little sedimentation, were perfect for navigation and generating energy through the water wheel technology (Tvedt, 2010, p.34). Therefore, during the 18th and early 19th centuries, the British had developed an extensive system of waterways for transporting coal and iron-ore deposits to industries and the finished industrial products to the market. Besides navigation, they used the water wheel technology for generating the power to run their textile and metallurgical industry. Consequently, during the industrial revolution, the British perception of water was that of a critical resource input for boosting industrial production. Besides, as discussed in Chapter 2, the widespread western attitude prevailing in England considered nature and water as essentials for facilitating human convenience and comfort (Pierotti and Wildcat, 2000, p.1334).

At first, when the British entered India, a few British officers such as Thomas Munro were highly impressed by the traditional water management systems in India (Narain, 2006, p.6). In the case of Karnataka, he observed that repairing the existing tanks would be a better choice than undertaking the construction of any new waterworks. However, by and large, the primary motive of the British in colonising India was to gain quick economic returns from its natural resources, including water (Naz and Subramanian, 2010, p.3). Therefore, for increasing the agricultural production in India, they decided to reconfigure the existing traditional water management systems through scientific and technological interventions. As a result, we observe the emergence of large dams, reservoirs and long canals during the British Colonial Period.

Similarly, after independence, some of the western-educated Indian nationalists had an image of a modern India wherein large dams symbolised its trajectory along the path of development and progress (Narain, 2006, p.6). At the same time, policy-makers and planners faced the challenge of fulfilling the water requirement of urban areas experiencing rapid demographic and spatial growth. As a result, we observe that during the Post-Colonial Period, there was an acceleration in the construction of large dams and the emergence of tubewell technology for extracting groundwater from deeper aquifers.

This chapter aims to understand this transition in the design and management of water infrastructure that took place during the British colonial and post-colonial period. It discusses the waterworks undertaken by the British and Indian governments in Pune during the 19th and 20th centuries. Simultaneously, it examines the long-term socio-ecological impacts of colonial and post-colonial water infrastructure and the way it altered the traditional practices of building water infrastructure. The timeframe under consideration in this chapter is divided into three periods as follows:

i) The period under British East India Company (1817-1857)

ii) The period under British Crown (1858-1947)

iii) The post-independence period (1947 onwards)

Figure 5.1: Timeframe showing the examples of water infrastructure during British-Colonial and Post-Colonial Periods.
Source: Author

The British entered India as traders at the beginning of the 17th century. The organisation of these traders was known as the 'Company of London trading with East Indies' popularly called as 'The British East-India Company (EIC)' (IGI-IV, 1909, P.6). In due course, along with establishing trade relations, the EIC gained control over several Indian Provinces. A representative of the EIC known as a 'political agent' was already present in the court of the Peshwe (GBP-XVIII, Part III, 1885, pp.409-409). In 1817, the EIC entered into a war with the last Peshwa – Bajirao II and defeated him in the Battle of Khadki (GBP-XVIII, Part II, 1885, pp.300-301). After his defeat, the EIC established its rule over Pune which extended until 1857. In the 1850s, there was tremendous unrest about the EIC's harsh policies and administration in the minds of Indians. This unrest resulted in the First War of Independence in 1857. Although the EIC emerged victorious in the war, the administration in Britain was shaken by the war. It dissolved the EIC, and itself looked over the administration of India through the appointment of a Viceroy who was the representative of the British Crown (IGI-IV, 1909, p.36). Thus, from 1858 onwards until 1947, the administration of India was directly controlled from Britain. Based on these two administrative periods of British colonial rule, the water infrastructure in Pune has been categorized into the same two periods – the British East Indian Company Period and the British Crown Period.

Section 5.1 begins with a discussion on the water infrastructure during the period of the EIC. For the convenience of discussion, it categorises the water infrastructure into two categories – urban and rural. Firstly, it discusses the measures undertaken by the EIC in maintaining the nahars of Pune, followed by the measures taken to maintain the traditional water structures in rural areas. The section ends by discussing the challenges faced by the EIC in maintaining the TWI of Pune.

Section 5.2 continues with the discussion on the water infrastructure during the period of the British Crown. Under the same two categories of urban and rural, it describes the water infrastructure of Pune and the irrigation infrastructure in the surrounding villages of Pune. It ends by shedding light on some of the negative impacts of colonial water infrastructure.

Section 5.3 begins with the discussion on post-colonial water infrastructure by briefly examining the ideas of modernity and progress prevailing in the minds of the Indian nationalists. It further discusses how these ideas accelerated the process of constructing large dams and expanding water supply and irrigation network. It sums up by drawing attention towards the supply-oriented water management approach of the Indian government and its adverse effects. The chapter concludes by summarising the key characteristics of the British colonial and Post-Colonial water management policies and their subsequent harmful effects.

5.2. Water infrastructure during the British East India Company (1817-1857)

After defeating Peshwa Bajirao II in the battle of Khadki, the EIC annexed Pune into the Bombay Presidency.[59] Under the EIC rule, Pune consisted of eight sub-divisions (GBP-XVIII, Part I, 1885,p.1). The town of Pune developed by the Peshwe was a separate sub-division. By the beginning of the EIC period, the water infrastructure within Pune mainly consisted of the wells and nahars. Besides, the other sub-divisions contained many structures harvesting rainwater and groundwater.[60] For convenience purpose, the water infrastructure can be classified into two categories – urban water infrastructure in Pune town and the rural water infrastructure

[59] A Presidency was a physical unit of administration under the Control of a Governor. At the time of EIC rule, there existed three important Presidencies – the Madras Presidency, the Bombay Presidency and the Calcutta Presidency (IGI-IV, 1909, p.7).

[60] The Gazetteer of the Bombay Presidency (1885) mentions the various water harvesting structures in the different sub-divisions of Pune in Part III, Chapter XIII – Sub-divisions (pp.75-101).

mainly in the sub-divisions. During the EIC rule, the responsibility of repairing and maintaining the urban infrastructure vested in the hands of the administrative staff of Pune working under the supervision of the Collector. Whatever maintenance work the staff planned to undertake required the prior approval of the Public Works Department of Bombay Presidency. The repair and maintenance of rural water infrastructure vested in the hands of the Military Board (Whitcombe, 1983, p.679). The primary utilisation of water in Pune was for domestic purpose, while in the other sub-divisions it was for domestic and irrigation purposes. Based on water utilisation, infrastructure and water policies vary. Therefore, the urban and rural water infrastructure during the EIC rule is analysed separately in the following subsections.

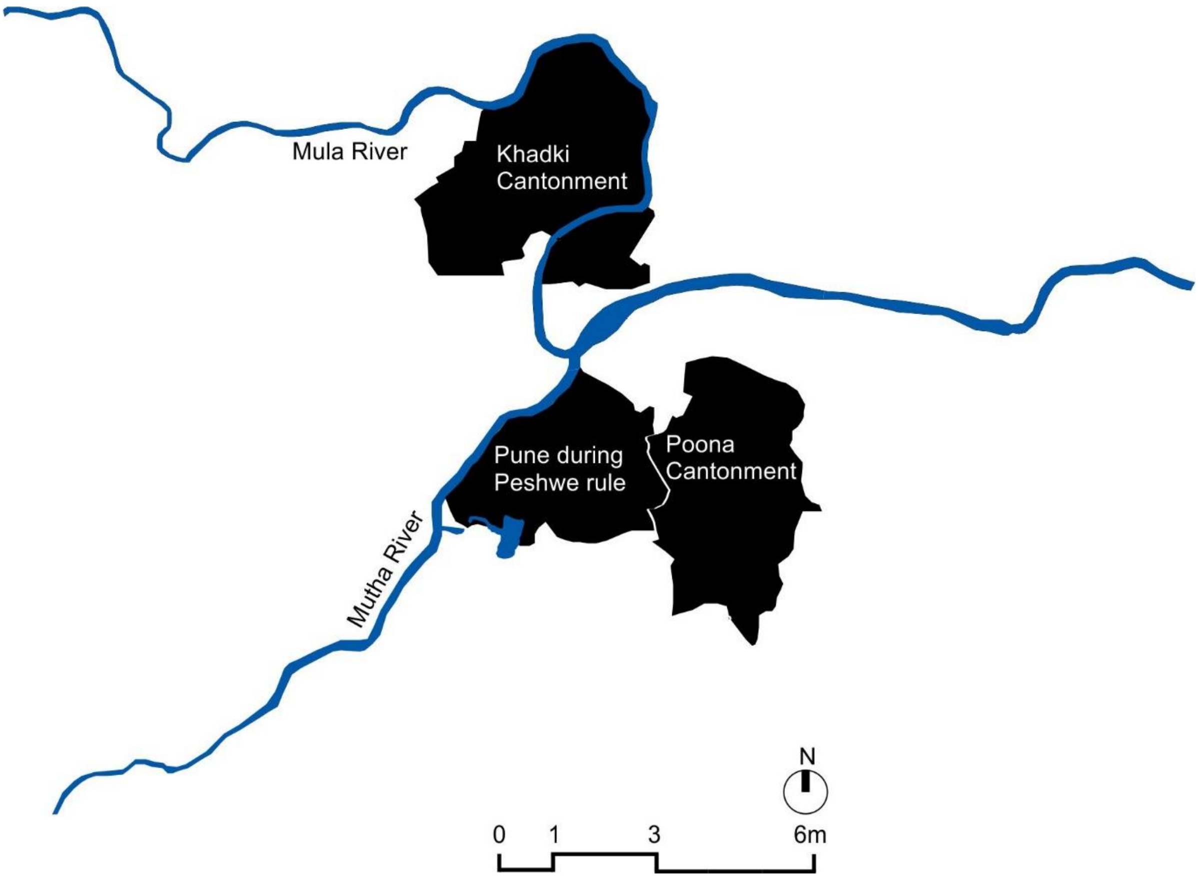


Figure 5.2: Map showing the location of British Cantonments in Pune.
Source: PMC, 2014, p.3.

5.2.1. Urban water infrastructure

After the conquest of Pune, the EIC established two cantonments – the Pune cantonment and the Khadki cantonment for encamping their military troops. In due course, the EIC fixed the boundaries of both the cantonments. The Cantonments were areas that consisted of two zones – the Military area and the Bazar area (Moledina, 1953, pp.5-6). The Military area comprised of the residences of military officers. The Bazar area consisted of business people known as 'camp followers' who provided the necessary services to the army. Thus, Pune during the rule of the EIC comprised of the town of Pune developed by the Peshwe and the two cantonments established by the British (refer Figure 5.2).

During the last few years of Peshwe rule, the population of Pune was about 110,000 (Kosambi, 1980, p.179). In 1822, Pune's population decreased to 79,000. This implies that even during the EIC's rule, the already existing streams, wells and nahars of Pune could have fulfilled the domestic water requirement of about 100,000 people. Therefore, in its initial years of rule, the EIC attempted to maintain the existing wells and nahars of Pune rather than undertaking the construction of any new water infrastructure. The Gazetteer of Bombay Presidency (1885, p.326) mentions the presence of 1290 wells in Pune as discussed before. However, since most of the wells contained brackish water, people used their water for bathing and washing purposes. In addition, people also used water from the Mutha, Nagzari and Manik Nala for bathing and washing purposes. The primary sources of drinking water were the four nahars built by the Peshwe. The four nahars altogether supplied Pune with 850,000 gallons (3.2 million litres) of water daily (GBP-XVIII, Part III, 1885, pp.326-327)as indicated in Table 5.2.

Table 5.1: Water supply by the four nahars of Pune in the 19th century.

Nahar origin	Built by	Year	Supply (gallons)	Supply (litres)
Katraj	Balaji Bajirao	1750	650,000	2,460,000
Kondhwe	Ruparam Chaudhary	--	50,000	190,000
Kondhwe	Anandrao Raste	--	50,000	190,000
Narhe Ambegaon	Nana Fadnavis	1790	100,000	380,000
		Total	850,000	3,220,000

Source: GBP-XVIII, Part III, 1885, p.327.

As observed in Table 5.1, the water supply by Katraj Nahar was maximum. It was almost 13 times more than the supply of the Kondhwe Nahars and 6.5 times more than the supply of Narhe Ambegaon Nahar. In addition, as seen in the previous chapter, its expanse was greater in comparison with the other three nahars. Realising the practical importance of the Katraj Nahar, the EIC took its control and started looking after its maintenance and repair. However, the EIC did not undertake the control of other three nahars. They were maintained by the descendants of Fadnavis, Raste and Chaudhary (GBP-XVIII, Part III, 1885, p.328).

Before starting the actual maintenance work, the EIC administrators in the Bombay Presidency had to follow a tedious administrative procedure. They had to explain the nature of maintenance work, prepare an estimate of proposed expenditure, and submit it to the Public Works Department of the Bombay Presidency (Hardiman, 1995, p.205). The Department then carefully scrutinised the estimate and asked for clarification on any of the proposed expenditure. They approved the work only after they were fully satisfied with the necessity of the maintenance work and the proposed expenditure. Upon approval, the EIC administrators in Pune could begin with the actual work. A report titled 'Measures undertaken for the general improvement of Poona City' [61] dated 17 May 1843 handed by the Public Works Department, Bombay to the Board of Control[62] in Britain enlists the various repair works in Pune that the Department approved during 1840-1842. The letters attached as enclosures to this report mention works that included repairing the Katraj talavs, repairing the nahars, their openings, filter screens, and so on. It is worthwhile to highlight some of the repair and maintenance works undertaken by the EIC, as listed in Table 5.2.

Table 5.2: Overview of the maintenance work undertaken by the East India Company.

Date of letter/ report	Nature of repair work
07-10-1841. No 272.	R. Mills, a civil servant requested the Government of Bombay Presidency to approve an amount of Rs 26 for purchasing locks for the doors of nahars. After seeking appropriate clarification from him, the Government sent a letter dated 07-01-1842, mentioning the sanction of the amount.
January 1842.	A report handed by the Superintendent of Roads and tanks to the Revenue Commissioner mentioned the clearance of 335,853 cu.feet (9510 cu.m) of mud from the Katraj talav. The work was so tiresome that the Superintendent suggested the Revenue Commissioner break the bund wall at two to three places and let the stream wash away the mud in monsoon.
05-02-1842. No 32.	John Warden submitted a bill of Rs 10.26 to purchase Dungree cloth for wrapping around the wooden plugs of the nahars. The government sent a later dated 22-02-1842, mentioning the sanction of the amount.
08-03-1842	John Warden submitted a bill of Rs 137 for repairing the openings that the Government sanctioned in the same month.

Source: Board of Control Records, 1843.

[61] The British referred to Pune as Poona.
[62] The Board of Control was established under the provisions of the Pitt's Act of 1784 for controlling the EIC's administration (IGI-IV, p.34).

Table 5.2 shows how for every minor maintenance work, the local administrators of Pune had to inform and take prior approval from the Public Works Department. This procedure often took several days or months. As Hardiman (1995, p.205) mentions, the water supply was just one of the works carried out by the Public Works Department along with the construction of roads and buildings. The process of obtaining a sanction for carrying out a repair work was time-consuming that often led to delays in carrying out the maintenance work. Besides, the repair and maintenance of the nahars had traditionally been the responsibility of the *beldars* and *mahars* who were part of the community and received money or goods in return to their services (Bhave, 1976, p.15). However, the EIC failed to understand these social relations embedded in managing TWI. Instead of involving traditional communities who had been responsible for the maintenance and repair work, the EIC hired prisoners from the Pune Jail to clear the mud deposition from the talavs.[63] Hiring the prisoners for carrying out the mud clearance became a laborious and time-consuming task for the EIC.

Amidst the difficulty in maintaining the nahar system of Pune, the EIC struggled to fulfil the water requirement of the Cantonment. As the nahars were restricted to the core area of Pune alone and the water nearby was polluted, the EIC decided to a have reliable source of clean drinking water to the cantonment (Moledina, 1953, p.76). In 1844, the EIC built a bund on the Mula River with the financial assistance by Jamshedjee Jeejeebhoy – a Parsi-Indian merchant (ibid). After the completion of the bund, water from the Mula was pumped into the reservoirs constructed in the Cantonment. However, it seems that the quality of water from the Mula was not satisfactory. Therefore, the water from the bund was utilised for a short duration. After that, in the 1850s, various engineers came up with different water supply proposals for fulfilling the water requirement of Pune and the cantonments. Captain Hart (1858) has presented a summary of these proposals in his letter to the Government dated 23 October 1857, as shown in Table 5.2 below:

Table 5.3: Summary of various projects for supplying water to Pune and the Cantonments.

Date	Proposal by	Area	Proposal	Expected expenditure (Rs)
9 October 1851	Vickajee Meerjee	Pune	Bringing water from a stream at Dhankawdi.	50,000

[63] A letter written by the Acting Session Judge of Poona to the Secretary of Bombay Presidency dated 19 March 1840 mentions that the Judge had hired prisoners for repairing an embankment across the Mula River (Board of Control Records, 1840, No 29).

		Cantonment and suburbs	Getting additional water supply from the Jamshedjee Bund.	160,122
31 October 1851	Captain Graham	Pune	Raising the wall of the Lower Katraj Talav.	18,402
		Pune	Getting water from Katraj Upper Talav.	66,704
		Pune	Increasing the supply of the nahar built by Nana Fadnavis.	-
		Cantonment	Increasing the supply of the Raste nahar.	2,727
		Cantonment	Combining the supply of Chaudhary and Raste nahars.	3,755
		Cantonment	Collect overflow of Raste nahar into two reservoirs in the cantonment.	4,000
		Cantonment	Building a new bund at Kondhwe and bringing water through nahar.	126,866
4 December 1851	Captain Jacob	Pune	Remove the silt from the lower Katraj Talav	
15 January 1852	Captain Kilner	Pune and cantonment	Bringing water from the upper Katraj Talav into cisterns in Pune and cantonment.	111,877

10 March 1853	Captain Barthon	Pune Cantonment	Construct a bund at Kondhwe and bring water to the cantonment. From there conveying water in pipes.	123,910
3 July 1855	Reeves	Pune and cantonment	Construction of a dam across the Mutha River near Sangroon and bringing water through iron pipes.	-
18 October 1856	Gerrard	Pune Cantonment	Constructing a dam across the Ambegaon valley and leading water through earthenware pipes to a reservoir in the cantonment. From there, supplying water through iron pipes.	248,917

Source: Adapted from Hart, 1858, pp.1-8.

Table 5.3 shows that most of the engineers proposed to repair or modify the already existing water sources like the Katraj Talavs and nahars for meeting the water requirement of Pune and the cantonments. The Chief Engineer of Public Works Department asked Captain Hart – the officer on special duty to select the most suitable of the proposals listed above. After accessing the various proposals, Captain Hart discarded the proposals that suggested bringing water from the Katraj Talavs. Captain Hart was aware of the difficulty in clearing the Lower Katraj Talav, as he had been the Assistant Superintendent of Roads and Tanks for Pune in 1839. After accessing the different proposals, Hart considered Gerard's proposal to be the most promising of all (Hart, 1858, p.12).

He further worked upon Gerard's proposal and submitted a report to the British Government in 1857. In his report, he assumed Pune Cantonment's population to be 40,000. With the assumption of supplying 20 gallons (75 litres) of water per head daily, he worked out the annual water quantity as 300 million gallons (1135 million litres). Based upon the water requirement, he proposed to construct a storage reservoir having an approximate area of 2700 acres at Ambegaon valley. His estimate for the entire project comprising the construction of reservoir, aqueducts and distribution network was Rs 449,463 (Hart, 1858, pp.15-16). However, the project did not materialise. In the opinion of other engineers from the Public Works Department, the Ambegaon Valley was shallow for storing the quantity of water as estimated by Hart. Therefore they searched for alternative sites from where water could be brought to Pune (Fife, 1866, pp.2-3).

Thus, the Jamshedjee bund was the only urban water structure constructed during the EIC Rule. Wells and nahars built during the Peshwe period continued to be the primary sources of urban water supply. Although the EIC attempted to maintain the Katraj nahar, it failed to understand the social dynamics behind the efficient functioning of the nahars. As a result, even though the EIC managed to take physical control of the nahar, it could not mobilise the necessary human resources required for its maintenance. Thus after discussing the EIC's effort in maintaining the urban infrastructure of Pune, the next subsection discusses the state of rural water infrastructure under the EIC rule.

5.2.2. Rural water infrastructure

At the beginning of the EIC rule, the main sources of rural water supply and irrigation were the wells, bandharas, baravs, kunds, and talavs. Irrespective of these diverse water sources, the EIC focused on the maintenance of wells and canals only. Coming from the European context, the EIC lacked an adequate understanding of the significance of rainwater harvesting in India. As Bhaduri and Singh (2012) argue, the concept of rainwater harvesting was absent in Britain as rainfall was evenly distributed over the year. Therefore, the EIC failed to understand the value of traditional rainwater harvesting structures in India (Bhaduri and Singh, 2012, p.9). It neglected these structures by categorising them under the head of 'other sources of irrigation' (Sengupta, 2007, p.135).

The sole objective of the EIC in undertaking irrigation works was the collection of revenue from the beneficiaries. For earning revenue, the canal system was the most suitable for the EIC administration as it allowed for central management and control. Accordingly, when the EIC attempted to document and categorise the various sources of irrigation in India, it recorded the wells and canals but classified the rainwater harvesting structures as other sources. This categorisation was suitable for the EIC revenue collection but unsuitable for capturing the rich diversity of rainwater harvesting structures (Sengupta, 1993, P.28). As a result, these valuable water structures were neglected as other sources of irrigation.

At the same time, it would be wrong to assume that the EIC neglected the traditional systems completely. Evidence reveals that in places such as Ajmer and Mewar, individual personnel of EIC held views that people should be encouraged to construct traditional water structures (Sengupta, 2007, p.132). However, in spite of people building tanks, the Military Board was responsible for their periodic maintenance. Instead of encouraging the communities to maintain the tanks, the Military Board employed prisoners for works such as repairing the embankments, clearing the silt deposition, and so on (as discussed in the case of traditional urban infrastructure). These outside people did not possess the same attachment and technical skills to the water structures as the traditional communities had. As a result, they failed to maintain the structures properly. Eventually, due to the accumulation of silt and other impurities, the structures became unsuitable for use (Bhaduri and Singh, 2012, p.15).

The EIC policy on land ownership and rents also had a detrimental effect on traditional systems. Traditionally in India, many people had common shared rights over land (Bhaduri and Singh, 2012, p.13). They often collectively owned a particular water structure. The EIC interfered in this traditional pattern of land ownership and introduced the concept of individual property rights. Consequently, most of the water structures that existed on common land came either under private ownership or government ownership, resulting in a separation of water rights from land ownership rights. Communal ownership had traditionally fostered collective responsibilities. With a change in ownership, loss of land rights, the water structures faced further neglect.

Similarly, the EIC changed the traditional 'produce-based' rent system to 'fixed rent system' (Sengupta, 1980, P.169). In the traditional produce-based rent system, the rulers fixed the rent based on the annual crop output. The maximum rent was 2/5th of the produce, which the farmers had to pay in cash or kind (Khobrekar, 2006, p.567). During droughts, when the harvest declined, the rulers reduced the rent. Due to this flexibility, the farmers were never burdened by the rent. The EIC changed this traditional method of rent collection. They fixed the rent beforehand, and it was independent of the annual crop output. Therefore, the poor farmers were overburdened by taxes when the annual production was little due to droughts.

Additionally, in the traditional system, the salary of the village head depended on the rent collected by him. Therefore, he encouraged people to increase their agricultural output by building water structures and bringing maximum land under irrigation. The EIC changed this traditional system and started paying a fixed salary to the village head. It did not depend on the rent collected by him from the farmers. As a result, the village head was disinterested in encouraging people to build new water structures and improving irrigation (Bhaduri and Singh, 2012, p.11).[64] Thus, the changes in land policy and rent system further led to the decline of traditional water structures.

This interference of the British in the traditional social institutions of India, corruption in the administration, and most importantly denying people their right to freedom created severe unrest amongst Indians. In the mid-19th century, this unrest reached a peak point and led to the outbreak of the First War of Independence. Although the EIC managed to suppress the

[64] Bhaduri and Singh (2012) explain this phenomenon by taking the case of ahar-pyne system in South Bihar. However, a similar social fabric was present in Maharashtra and therefore their observation is valid for the traditional systems of Maharashtra.

growing unrest and emerged victorious, it also suffered heavy losses in the war. The British Parliament dissolved the British East India Company. It passed the Government of India Act in 1858 (IGI-IV, 1909, p.16). By this act, the administration of India was controlled from Britain. The Governor-General of India, known as the Viceroy, headed the Indian administration and was appointed directly by the British Crown (ibid). During the rule of the British Crown, the water infrastructure underwent significant changes, as seen in the following section.

5.3. Water infrastructure during the British Crown (1858-1947)

The transfer of power from the EIC to the British Crown brought in some significant reforms in water supply and irrigation. One of the administrative changes was the abolishment of the Military Board and establishment of a central Public Works Department looking after the construction, repair, and maintenance of both water supply and irrigation works (Whitcombe, 1983, p.691). A top-down hierarchical administrative setup handled the issues related to water supply and irrigation, as shown in Figure 5.2.

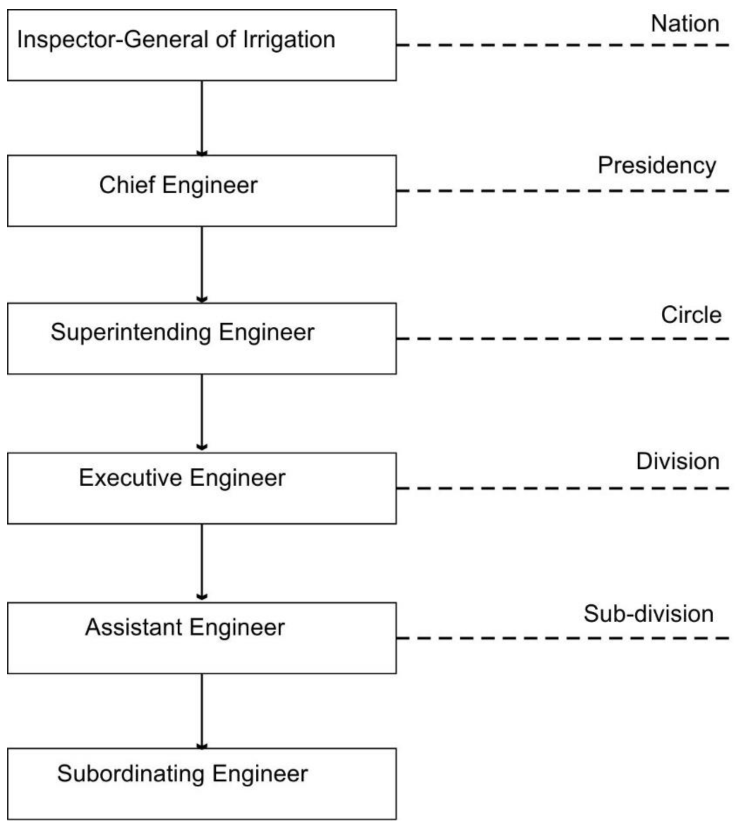


Figure 5.3: Diagram showing the hierarchy in the Irrigation Department
Source: Buckley, 1880, pp.51-52.

Buckley (1880) has described the administrative setup of the irrigation department. At the top of the organisational structure was the inspector-general of irrigation. He was attached to the staff of governor-general of India. Below him were the chief engineers of various presidencies. They were the heads of the Public Works Department in the presidencies. The administrative area of a presidency was divided into circles. Every circle had a superintending engineer. Each circle was further divided into divisions which were presided by executive engineers. Also, every division had a sub-division presided over by an assistant engineer who worked with the support of his subordinate staff. The superintending engineer had the authority to sanction works involving any minor expenditures. Works that included substantial investment needed the approval of the chief engineer. Construction of any new project required the approval of the inspector-general and the Secretary of State in Britain (Buckley, 1880, pp.51-52).

With the setting up of a hierarchical top-down administrative setup, the British made laws for water supply and irrigation in the British Presidency. The laws mainly vested the complete rights over water to the British administration. The preamble of the Bombay Act. No VII of 1879 related to the construction, maintenance and regulation of canals contained the following provision:

Whenever it appears expedient to the governor in council that the water of any river or stream flowing in a natural channel, or of any lake, or any other natural collection of still water should be applied or used by the government for the purpose of any existing or projected canal; the governor in council may, by notification in the Bombay Government Gazette, declare that the said water will be so applied or used after a day to be named in the said notification, not being earlier than three months from thereof.

At any time after the day so named any canal officer duly empowered in this behalf may enter on any land, remove any obstruction, close any channel, and do any other thing necessary for such application or use the said water, and for such purpose may take with him, or depute, or employ such subordinates and other persons as he deems fit. (Buckley, 1880, p.54).

The act was formulated so that the British could undertake the construction and maintenance of water infrastructure in the broader public interest. However, in reality, misuse of the act allowed the British in gaining absolute control over the natural water sources in the Presidency. As mentioned in the previous section, the system of canals was the most suitable for the British to gain absolute control over the natural water sources. Therefore, during the period of the British Crown, Pune witnessed the construction of several large dams and canals both for domestic and irrigation purpose as seen in the following section.

5.3.1. Urban water infrastructure: Piped water system for Pune city

Under the regime of the British Crown, water management vested in the hands of a governmental planning and maintenance agency. In 1856-1857, a Municipality was set up for managing the affairs of Pune. Similarly, a Suburban Municipality was set up in 1884 to look at the newly developed areas near the cantonments (GBP-XVIII, Part III, 1885, p.323, 359). Both the municipalities had to plan for the water supply systems in their jurisdiction. During the rule of the British Crown, Fife came up with the proposal of constructing a dam across the Mutha

River at Khadakwasla and supplying water to the Pune city, Pune Cantonment, Khadki Cantonment and few suburban areas (Fife, 1866).

In Fife's opinion, small reservoirs were useless in the Deccan region as they quickly dried up during the hot summer months. He cited the example of Vehar Lake of Bombay wherein the quality of water deteriorated in the summer months. He compared it with the proposed lake at Ambegaon by Captain Hart. The lake at Ambegaon was 1/17th the size of the Vehar Lake. Therefore, Fife was of the opinion that the lake at Ambegaon would fail to provide the necessary quantity and quality of water to the Cantonment during the summer months of April and May. Besides, Hart had taken into consideration the water supply of the Pune Cantonment alone. In 1865, there was a need to have a new water supply system for Pune with the increase in its population. Therefore, Fife had to take into consideration the total water requirement for Pune city, its suburbs, Pune Cantonment and Khadki cantonment. Hart's proposal would have undergone a substantial modification and added to the overall cost of the project for meeting this additional water requirement (Fife, 1866, pp.2-6).

As a result, Fife came up with a new proposal for constructing a dam at Khadakwasla and conveying water to Pune. He planned the project in such a manner that both Pune and Cantonment would each receive a daily water supply of 5.7 million litres. Similarly, the Khadki cantonment would receive a daily water supply of 3.5 million litres. The overall cost of the project was estimated to be Rs 1,653,049 (Fife, p.11). While working on the water supply project for Pune and its cantonments, Fife was simultaneously working out a proposal for irrigating the agricultural land around Pune. He wrote to the government about the possibility of combining both the projects. His suggestion was to build a single large dam at Khadakwasla and create a reservoir that would meet both the domestic and irrigation water demands simultaneously. The Government approved his proposal. The work commenced in 1869 and was partially completed in 1879 (GBP-XVIII, Part II, 1885, p.20). The overall project comprised of the reservoir at Khadakwasla known as Lake Fife; two open canals, one was running along the right bank and the other running along the left bank of the river Mutha; service reservoirs and distribution network.

The entire scheme of Fife became operational in parts. Khopkar (1951) mentions that there were two distinct arrangements for supplying water to the city and the cantonments. Pune city received its water supply from the Mutha Right Bank Canal. Water from the canal was brought into a filtration plant near Parvati. Fife had proposed to utilise the Parvati talav as a backup reservoir. From the filtration plant, water was pumped into high-level tanks located in the Eastern part of the city. From there, the distribution of water throughout the eastern part of the city took place. As the western part of the city was at a lower level, the distribution of water took place by gravitation (Khopkar, 1951, pp.29-30). Similar to the arrangements for Pune city, there were two settling reservoirs in the Poona Cantonment. The two settling reservoirs received water from the Mutha Right Bank canal. From the reservoirs, water was distributed to different parts of the Cantonment, partly through pumping and partly by gravitation. Similarly, the Khadki Cantonment had two service reservoirs from where the distribution of water took place across its parts (GBP-XVIII, Part III, 1885, p.328).

In the year 1876-1877, 549 houses in Pune had water connections. The Municipality levied a tax for utilising water from the Canals. In the year 1877-1878, the municipal income from the water tax was Rs 7810 (Khopkar, 1951, p.29). In 1882-1883, the daily water supply to Pune was 6.82 million litres (PMRPB, 1970, p.112). However, it seems that Pune did not have a network of piped water supply until the beginning of the 20th century. The Regional Plan for Pune Metropolitan Region 1970-1991 mentions that the first piped water supply scheme for Pune began in 1908 and was completed in 1915. This scheme was designed for a population of 121,000 (ibid). Along with the introduction of piped water supply, the construction of the first underground sewage system took place in 1910. The sewage system had an impact on the water supply scheme.

The sewage system of 1910 served a population of 119,000 (PMRPB, 1970, p.128). It served a limited portion of the city. In 1929, a joint scheme for the Pune Municipality, Pune Suburban Municipality, Pune Cantonment Authority, and the local Railway Administration was prepared. It was completed in 1931. Although the scheme could not cover the entire expanse of Pune city due to geographical barriers, it led to a substantial increase in the water requirement. Water was required both as a medium for conveying the solid waste and for diluting it. However, the original water supply scheme completed in 1915 had not considered the water required for conveying the sewage. Therefore, after the completion of the sewage system, a new water distribution system had to be designed for fulfilling a daily water requirement of 182 litres, a quantity double of the original (ibid). Thus, the operation of the sewage system doubled the water demand of Pune.

From the above discussion, one may argue that the demographic and spatial growth of Pune City prompted the British to undertake the construction of Lake Fife, the Mutha Canals and the piped water network. Although this a reasonable argument, instead of constructing such a large project, it was possible to build several smaller projects that were cost-effective and sustainable. Limiting the discussion to urban water supply alone, one can observe that in spite of the considerable investment, the return was meagre. Only a few privileged people could purchase the water from the scheme. Furthermore, some of the high-level areas were underserved by the scheme. Therefore, many people from the core area of Pune were still dependent on the water supply of nahars. In short, the scheme had limited success in meeting the increased water demand. Even in the rural areas, the scheme failed to achieve the expected results as seen from the report of the Irrigation Committee (1901) discussed in the following section.

5.3.2. Rural water infrastructure: Large dams and canals

The period of the British Crown reflects the way water infrastructure (especially irrigation) becomes critical due to economic losses caused by natural calamities. During the period of the British Crown, for economic reasons, the irrigation department classified all the irrigation works into two classes – Major and Minor works (Buckley, 1880, pp.29-30). Major works were those, which the British constructed and were important from an engineering point of view. Minor works were generally improvements or modifications to the already existing traditional irrigation works. Based on the source of finance, irrigation works were classified as productive and protective works. Productive works were built from borrowed capital. Therefore, gaining profit from them was the main consideration to pay back the interest on the borrowed capital. Protective works were constructed from the revenues of India. As their name suggests, the purpose of their construction was to protect agriculture from famines. Besides, in the construction of protective works, the British hired the famine-affected people as labourers. In this way, the famine-affected people could get the necessary financial support at the time of crisis.

Thus, in Pune, the British constructed the Nira canals and the Shetphal tank as protective irrigation works and five other as productive irrigation works (Irrigation Works Department, 1907, pp.4-5).

Table 5.4: Area irrigated by productive and protective irrigation projects in Pune during 1946-47.

Type of work	Year of completion	Name of the project	Area under irrigation (ha)
Productive (minor)	1869	Kasurdi tank	-
Productive (minor)	1878	Matoba tank	1,315
Productive (minor)	1878	Shirsuphal tank	728
Productive (major)	1879	Mutha canals	6,800
Productive (minor)	1881	Bhadalwadi	809
Protective	1884	Nira canals	46,295
Protective	1901	Shetphal tank	1,700
		Total	57,647

Source: Irrigation Works Department, 1907; GBS-XX, 1954, p.234.

Table 5.3 shows that the Mutha and the Nira canals were the primary sources of irrigation. Landholders who wished to utilise the canal water had to approach the subordinate staff of the canal (GBP-XVIII, Part III, 1885, p.14). They had to fill up a form and mention to the staff about the type of crop they would cultivate and the duration for which they would be using the canal water. At the end of the season, the subordinate staff measured the total irrigated area and fixed the charges for utilising the canal water accordingly. Every year the government set water rates per acre of land irrigated. Therefore, the total charges were calculated by multiplying the water rate by the total irrigated area. The Collector was responsible for recovering these charges from the landholders as fixed by the canal authority (ibid). According to the Irrigation administration report 1941-1942 by the Public Works Department, the annual percentage return on the total capital outlay for the Mutha Canal was 5.17%. For the Nira Right Bank Canal, it was 1.65%; and for the Nira Left Bank Canal, it was 6.03% (PWD, 1942, p.8).

The irrigation projects initiated for drought-proofing the region of Pune were successful to a limited extent. By 1947-48, when the British rule ended, 78,745 ha of land, about 9% of the total cultivated land was under irrigation (GBS-XX, 1954, p.230, Table no. 35). There was an overall increase of 3.8% in the area of irrigated land from 1896 to 1947 (from 69,130 ha to 78,745 ha).

In addition to the irrigation works, the British also started a few hydroelectric power plants towards the end of the nineteenth century. In 1919, the Government of Bombay granted the permission to a private company called Tata Power Company to set up a hydroelectric power plant near Mulshi in the outskirts of Pune (Rodrigues, 1998, pp.110-111). The project included the formation of an artificial lake by constructing a dam across the Mula River near Mulshi and an aqueduct for carrying water from the reservoir to the powerhouse. Upon completion, the hydropower project was expected to generate about 110,000 kW of electricity for the mills and industries around Bombay (ibid).

Thus, the investments made by the British in drought-proofing Pune through irrigation and setting up of hydroelectric projects highlight the economic perspective of looking at water. However, excessive irrigation and hydroelectric projects had adverse socio-ecological effects as seen in the following section.

5.3.3. Socio-ecological impacts of British Works

Neglect of traditional water wisdom and infrastructure

The traditional water infrastructure in Pune and the surrounding region was developed over several generations through careful observation of the terrain and rainfall pattern. Even the agricultural pattern, choice of crops to be cultivated depended on the rainfall pattern. However, as Gilmartin (1994) states, for the British, universal theories of science, mathematical models were the only means of achieving efficiency in irrigation. While some of the British administrators did value the traditional wisdom, majority of the engineers believed that a complete transformation and control of Indian environment was possible only when local knowledge became a subordinate to universal knowledge and science (Gilmartin, 1994, p.1144).

The British neglected the traditional water infrastructure because it did not meet their remunerative objective. As the British were unwilling to spend on the maintenance work of the traditional water infrastructure, it became difficult for the communities to maintain it themselves. Traditionally, the communities had always been financially dependent on the rulers for maintaining the water infrastructure. With the lack of any financial support, the communities were compelled to depend on the canal water and eventually gave up the maintenance of the traditional water infrastructure. Therefore, the area of land under irrigation from traditional water sources decreased significantly even though there was an increase in the overall area of irrigation, as seen in Table 5.5.

Table 5.5: Increase in land area under irrigation from 1896-1947.

Year	Area irrigated in percentage				Area irrigated in ha	Percentage of irrigated area to total cultivated area
	British Government Work	Wells	Traditional sources (private canals + other sources)	Total	Total	
1896-1897	17	71	12	100	69,130	5.0
1947-1948	60	38	02	100	78,745	8.8

Source: IIC, 1903, pp.372-373; GBS-XX, 1954, p.230.

As seen in table 5.4, in about 50 years, although the percentage of irrigated land increased by 3.8%, the percentage of land irrigated by traditional sources decreased significantly by 12%. Even the percentage of land irrigated by groundwater structures such as wells declined considerably by 32%. At the same time, the area irrigated by British canals increased substantially by 43%. The British encouraged the farmers to utilise canal water for cultivating water-intensive crops like sugarcane. Large-scale cultivation of sugarcane altered the traditional agricultural practices that were closely linked with the availability of water and soil conditions in Pune (IIC, 1903, p.70).

Extensive cultivation of sugarcane and giving up the cultivation of drought-resistant crops

A substantial portion of Pune received moderate rainfall and was occasionally prone to the occurrence of droughts. As a result, many of the farmers traditionally cultivated drought-resistant crops that required less water. With the beginning of canal water supply, most of the farmers started cultivating sugarcane. In 1941-1942, 45% of the net irrigated area was under sugarcane (PWD, 1942, p.9). As sugarcane is a water-intensive crop, most of the canal water was utilised for its cultivation. Extensive cultivation of sugarcane resulted in waterlogging and making the land infertile. Furthermore, the cultivation of sugarcane was concentrated within a radius of the first few kilometres around the head of the canal. This pattern of sugarcane cultivation restricted the distribution of canal water to a larger area (IIC, 1903, p.70). The benefit of protective irrigation works thus benefitted the wealthy landowners alone and deprived the poor farmers of their benefits (ibid).

Displacement of nine thousand farmers due to Mulshi hydroelectric project

The Tata Power Company built the dam at Mulshi at the expense of 9000 farmers losing their land (Rodrigues, 1998, p.111). Mulshi had extreme fertile land and was the chief supplier of famous *Ambemohor Rice* to Pune. The dam that was supposed to be built at Mulshi would have caused the submergence of 10,000 acres of land. Besides, it would have led to the displacement of 9000 farmers from 54 different villagers. Therefore, the villagers opposed the construction of the dam. They refused to surrender their lands and declined the offer of receiving compensation. The farmers launched a *Satyagraha* in 1921 under the leadership of Pandurang Mahadeo Bapat (1880-1967).[65] However, the British and the Tata Company managed to create a divide between the farmers. A few wealthy farmers who held large parcels of land agreed to accept compensation. While the compensation benefitted them, many of the poor farmers lost their lands and received meagre compensation. Thus, poor farmers lost their traditional association with land in favour of supporting the British Crown's vision of economic growth and progress (ibid).

Economic losses due to the construction of large dams

The British set up an irrigation committee in 1901 for inspecting the success of irrigation works in India. The report of the committee mentioned the economic losses of large irrigation tanks in the Deccan. In spite of the considerable capital investment on large projects in and around Pune, their net return was less than 2%, in comparison to the net gain of around 5% for entire India (IIC, 1903; Whitcombe, 1983, p.314). In conclusion, the committee stated,

[65] Pandurang Mahadeo Bapat was a believer in Gandhian Philosophy of truth and non-violence. Satyagraha means holding on to truth. It is a passive, non-violent form of civil resistance (Gandhi, 1928, p.108; Singh,1997, p.521).

(.....) If the Government wished to spend, say, a crore [66] of rupees on rain-fed tanks, it would be better to make, say, fifty small tanks at some distance from each other, than five large tanks, which cost over 20 lakhs [67]. (....) A tank with a very large catchment area is likely to receive a higher proportion of its full supply in a year of drought, than one with a catchment area one-tenth the size but not a higher proportion than ten such small tanks would receive. (....) we think that the advantages of large tanks in the region of uncertain rainfall have been over-rated. (IIC, 1903, pp.67-68).

The irrigation report concluded that as far as the region of Deccan is concerned, large irrigation projects failed to meet the productive objective. The report further mentioned that there were several small irrigation works in Deccan which irrigated annually an area of about 125,000 acres. Although it was not possible to extend these works, the report suggested that there was a scope to increase the number of such small irrigation works (ibid).

To sum up, the British policy of gaining central control over water interrupted the long-established practice of maintaining the traditional water infrastructure channelled the collaboration between rulers and communities. With canal water readily available to the people of Pune, the traditional water infrastructure became less valuable to the people of Pune. Extensive irrigation also led to adverse socio-ecological impacts. In spite of these impacts, after attaining independence, the Indian Government followed the British trajectory and emphasised the construction of large irrigation projects. It considered the development of large dams as a symbol of progress and modernity. The next section discusses these ideas and examines their impact on the traditional water infrastructure of Pune.

5.4. Water infrastructure during the Post-Colonial Period (after 1947 A.D.)

Soon after India attained independence in 1947, two prominent viewpoints emerged regarding its future path towards development. On the one hand was the Gandhian view, which firmly believed that India would enjoy the success of development only if its villages and agricultural economy were strengthened. On the other hand, the Nehruvian view believed that the only way in which India would develop is through rapid industrialisation and promotion of modern science (Guha, 2007, p.201, 215). Amongst the two viewpoints, the view of Nehru influenced the Indian administrative class and capitalists. As the First Prime Minister of India, Jawaharlal Nehru who attained his higher education from Cambridge was extremely fascinated by modern science. He considered science to be the spirit of the age. Similar to Nehru, Babasaheb Ambedkar, the architect of the Constitution of India, who had attained his higher education from Columbia University and London School of Economics, and was fascinated by large river valley projects (Baghel, 2014, p.10). The ideology of Nehru and Ambedkar is reflected in the irrigation policies and water infrastructure that came up in independent India.

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[66] 1 crore= 10 million
[67] 1 lakh = 100 thousand

Nehru was particularly influenced by the progress of Soviet Russia and Japan (Guha, 2007, p.205). He believed that large economy sectors like energy, infrastructure and transport needed to be entirely under the control of the Government. Therefore, all the natural water sources, especially rivers, were under the control of the State Government who decided how and for what purpose should their water be utilised. Nehru and other Indian intellectuals were greatly influenced by the Tennessee Valley Project of the US. Nehru was so fascinated by such large river valley projects that he called large dams 'the temples of modern India' (refer Chapter 2). Large dams were considered to be the symbols of modern and progressive India. As a result, India witnessed the construction of more than 700 dams in the two decades after independence from 1951-1970 (NRLD, 2017, Abstract of Large Dams). These dams were constructed for fulfilling the increased water demand in metropolitan cities, the spread of irrigation, and generating hydroelectricity.

Bound to the larger national-level interest, Pune also witnessed a similar expansion of centralised water infrastructure and construction of several large dams after independence. The next two subsections discuss the water infrastructure in Pune against the background of its demographic and spatial expansion and its impact on the traditional water infrastructure.

5.4.1. Urban water infrastructure: Expansion of the piped network

After independence, the Pune Municipality and the Suburban Municipality were merged, and a single Municipal Corporation was set up in their place in 1950 (PMC, 1952, P.4). The water supply department of the Pune Municipal Corporation (PMC) looked after the provision, repair and maintenance of the water supply in Pune. The Master Plan of Greater Poona published in 1952, mentioned the state of traditional water infrastructure at that time. As mentioned in the master plan, the three streams – Nagzari, Ambil Odha and Manik Nala were still flowing through Pune. However, as an improvement measure, the master plan suggested channelising the streams. It further recommended covering the streams with thick slabs and utilising the area thus gained as a footpath. Accordingly, the three streams were covered with slabs in many places (PMC, 1952, p.22). This approach indicated the first step in making the traditional water infrastructure invisible, which followed the discourse on technical systems being invisible and contradicting the socio-spatial and socio-technical nature of traditional systems.

In the case of the four nahars, the only nahar that was functional was the Katraj Nahar. The other three nahars built by Fadnavis, Raste and Chaudhary, had become non-functional in 1950 (Khopkar, 1951, p.29). The Parvati Talav was an important component of the Katraj nahar, as already discussed in Chapter 4. Even after the construction of the Mutha canals, it was a critical backup reservoir. Its water could be utilised during the maintenance of the canals. Additionally, the talav was a scenic place within Pune. In spite of its utilitarian and aesthetic values, the PMC neglected it, and soon it was filled with debris (Sowani, 2017, p.108). The PMC could have repaired and maintained it. Instead, the Municipal Corporation filled the talav with mud, levelled it and converted it into a garden in 1968 (ibid). Although the garden served as a useful public place, Pune lost an important urban water body. Even though the water from the Katraj Talav would not have been utilised for domestic purpose, the presence of clean water could have significantly improved the microclimate of the surrounding area.

On the one hand, traditional water infrastructure remained in a state of neglect. On the other hand, the Municipal Corporation undertook the work of expanding the piped water supply network built by the British within Pune. From 1950 onwards, the water supply scheme constructed by the British proved to be inadequate for fulfilling the water demand of the increasing population. The Master Plan of Poona, 1952 proposed to undertake a scheme that would assure a water supply of 150 litres per head per day to a projected population of about 2,000,000 (PMC, 1952, p.18). According to the proposal in the Master Plan, the construction of the Panshet dam was undertaken in 1957 (Gogate, 1988, p.7). The dam was located towards the west of Khadakwasla Dam, in the upstream area of River Mutha. Another dam at Varasgaon was constructed in 1976 across the Mutha (NRLD, 2017, Maharashtra State, sr.no. 576). The reservoirs of Panshet and Varasgaon Dam acted as storage reservoirs through which water was conveyed into the Khadakwasla Dam. From the Kahadakwasla Dam, water was taken into the Parvati Water Works for filtration and treatment (PMRPB, 1970, p.112). From there, it was distributed to different parts of Pune.

The Pune Municipal Corporation since its inception followed a supply-side water management approach. Based on population projections, the Water Supply Department worked out the future water requirement of Pune. It then thought of increasing the storage capacity of dams or found a new source of water. However, the water supply network has always found it challenging to keep pace with the increasing population and physical growth of the city. Table 5.6 and Figure 5.2 show the increase in area and population of Pune and the corresponding increase in the water requirement.

Table 5.6: Increase in Pune's area, population and water consumption (1950-2020).

Period	1950-60	1960-70	1970-80	1980-90	1990-2000	2000-10	2010-20
Area of Pune (sq.km)	139	146	146	243	243	243	331
Population (million)	0.48	0.6	0.85	1.20	1.69	2.54	3.11
Annual water consumption (TMC)	1.29	1.89	5.00	7.20	8.00	11.50	16.00

Source: PMC, 1952, p.4; Ghate, 2011, pp.1-28; PMC, 2014, p.15, Mundhe and Jaybhaye, 2017, p.47.

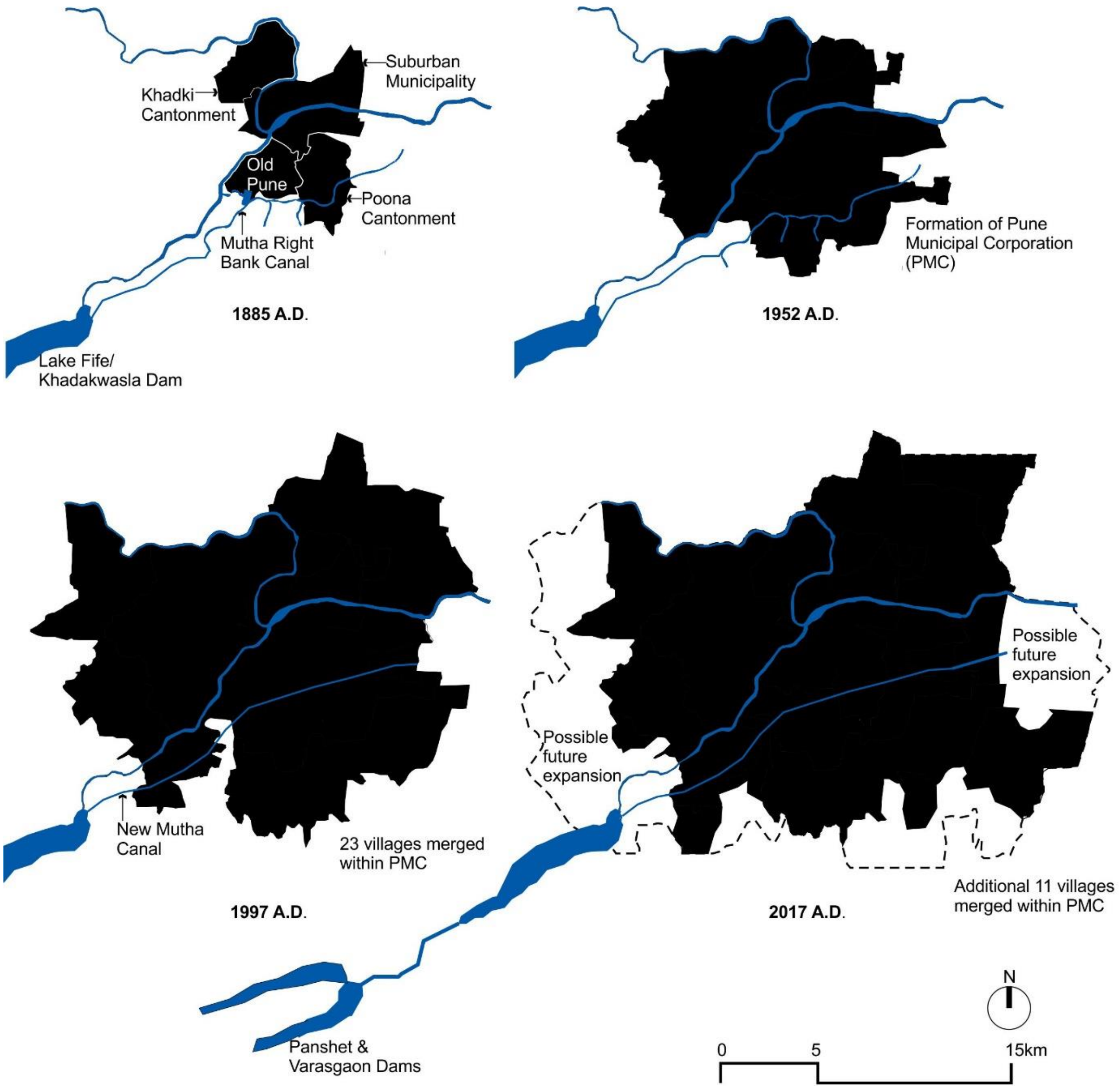


Figure 5.4: The spatial growth of Pune from 1885 to 2017.
Source: PMC, 1952; PMC, 2014, p.3.

Table 5.6 shows that since the formation of PMC in 1950, there has been a six-fold increase in the population of Pune, while its area has more than doubled over the past six decades. Simultaneously, its water consumption has increased by 15 TMC within the past six decades. Considering this rapid demographic and spatial expansion of Pune, PMC has attempted to fulfil the rapidly rising water demand through the extension of piped water supply grid. However, at the same time, PMC has failed to manage water demand, have equity in water distribution and protect the existing TWI from the pressure of urbanisation.

Currently, the annual water consumption in Pune is about 15 TMC[68]. PMC purchases this quantity of water from the Irrigation Department of Maharashtra State at the rate of Rs 2.64

[68] Shinde, P. D. Interview by Manas Marathe, 6 March 2018. Refer appendix for details.

for every 10,000 litres of raw untreated water. It then treats this water at its water treatment plants and supplies it to various parts of the city. Thus, the per capita per day water consumption in Pune works out to be 340 litres. However, almost 35% to 40% of this water is lost in distribution. Consequently, only 190 litres of water remains for the actual use of people. Nevertheless, even this daily water supply is higher than the 150 litres water supply prescribed by the planning standards, clearly indicating an excessive water use in Pune (MUD, GOI, 2015, p.315). Furthermore, the distribution of the available water in the city is unequal. The statistics from the PMC show that some areas of the city receive as high as 358 litres of water while some areas receive as low as 138 litres of water (PMC, 2018). Even the duration of water supply shows variation. Certain parts of the city receive water for 20 hours a day while certain areas receive it for only 2 hours a day (ibid). These statistics indicate that there is excessive water loss and uneven distribution of water in the city.

In addition to the problem of inefficient water supply, the current piped water network fails to reach to the peripheral areas of Pune. Often, the PMC extends the piped water network to the peripheral areas, but they do not receive water. In the hope of having a piped water connection, many people neglect and discontinue the use of existing TWI. Finally, they do not have access to piped water supply nor do they have the possibility of using water from TWI. Currently, PMC operates about 1100 registered municipal water tankers[69] to supply water to these peripheral areas[70]

To summarise, the PMC's aspiration of achieving the networked infrastructural ideal has remained unaccomplished. As a result, multiple mechanisms of water supply co-exist along with the centralised municipal water supply network. The situation in the villages around Pune is similar. The practice of constructing large dams for irrigation purpose had limited success, as seen in the following section.

5.4.2. Rural water infrastructure: Large dams for irrigation

In 1947-48, the net irrigated land in Pune was 78,745 ha. The percentage of irrigated area to the net cultivated land was 8.8% (as seen in Table 5.5). To envisage a substantial increase in the agricultural production, the First Five Year Plan (1951-1956) [71] of India had recommended the need to expand irrigation in India (Planning Commission, 1951, Chapt.32) Accordingly, different state governments had aligned their state-level irrigation policies to meet the goal of increased agricultural production set at the national level. As part of its irrigation policy, the State Government of Maharashtra was responsible for expanding the irrigation facilities in

[69] Water tankers are containers loaded on trucks having a storage capacity ranging from 6000 litres up to 12,000 litres. These containers are filled directly at Municipal water treatment plants and carry water to the areas that are unserved by the municipal water supply network. Apart from the municipal corporation, several private operators also supply water illegally Gaikwad. (Interview by Manas Marathe, 14 February 2018).
[70] Gaikwad. Interview by Manas Marathe, 14 February 2018.
[71] Five Year Plans in India are national level planning and economic programs envisaging the future line of socio-economic development (Planning Commission, 2013, p.2).

Pune. To monitor the progress in agricultural food production and irrigation, the Ministry of Agriculture at the National level compiled agriculture-related information from various State Governments in the form of an annual Seasons and Crop Report (Sengupta, 1993, p.19). Later, from 1970 onwards, it started undertaking a national level Agricultural Census that contained detailed state-wise information about the agricultural food production and irrigation (Agricultural Census, 2015, p.7). These various agricultural census reports prepared by the Maharashtra State Government in line with the national guidelines contained information about the expansion of irrigation in Pune. The information about the various sources of irrigation, as mentioned in these reports, is presented in the following bar diagram.

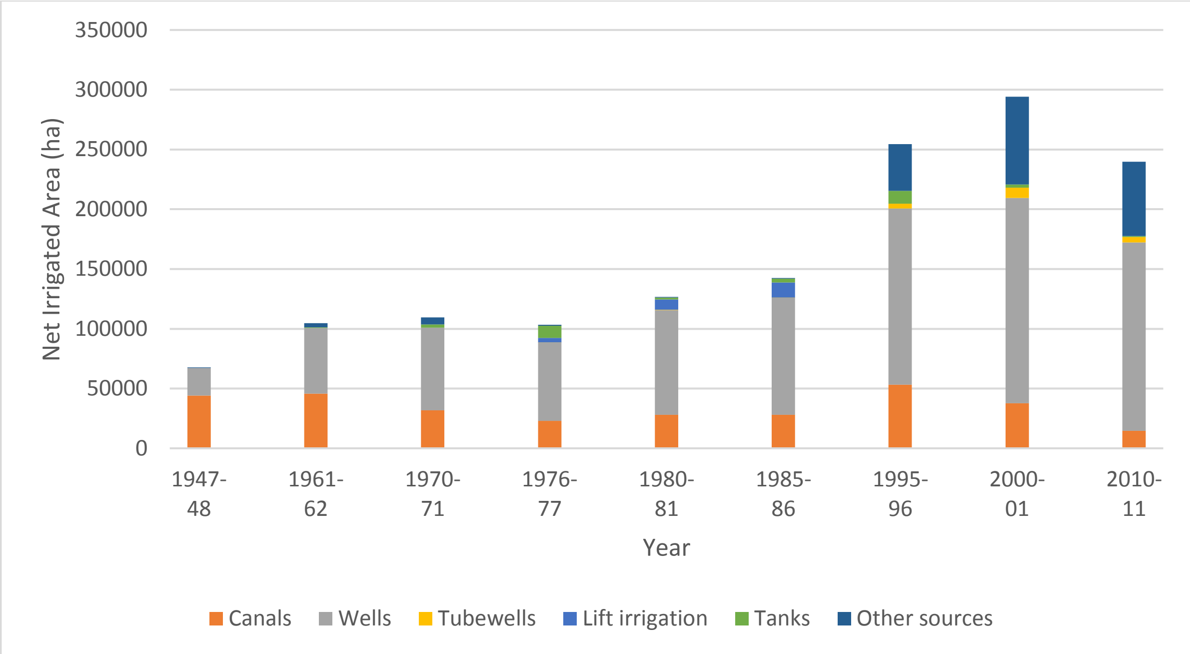


Figure 5.5: Different sources of irrigation in Pune from 1947-2011.
Source: Agricultural Census Division, agcensus.dacnet.nic.in/DistSizeClass.aspx, accessed on 17-08-2017.

The following observations can be made from the above bar diagram:

i) The area irrigated by canals has been irregular. It expanded gradually within the first decade after independence. Then the area showed a decline and a sharp increase in the decade from 1986-1996. Since then, it had reached an all-time low in 2010-11.

ii) During the 15 years from 1996-2010, there has been a sudden increase in the area of land irrigated by other sources of irrigation.

iii) Only the years 1976-77 and 1995-96 show land irrigated by tanks. For all the other years, the area under tank irrigation is insignificant.

iv) There has been a constant increase in the area irrigated by wells. From 1995 onwards, irrigation has also depended on tubewells.

The observations do not give a clear picture of the success of surface water irrigation. However, the steady progression in the number of wells and tubewells indicates the dependence of agriculture on groundwater for irrigation. The exploitation of groundwater has caused depletion of the groundwater table in many villages of Pune as already mentioned in the introduction.

Along with inadequate irrigation facilities, the rural areas of Pune lack access to clean drinking water. A recent study conducted by Hui and Wescoat (2019) shows that about 22 villages in Pune completely lack access to clean drinking water, i.e. they have drinking water away from their premises. Similarly, another 150 villages, mainly from central and eastern Pune, have inadequate access to drinking water. Overall, they identified around 414 villages in the periurban areas of small towns that needed to have improved access to drinking water (Hui and Wescoat, 2019, p.264).

Thus, the current centralised water infrastructure struggles to provide equal and adequate access to water in Pune, the peripheral areas around Pune and the villages within Pune District. The existing water infrastructure also faces the risk of failure. Leakages from water supply pipes is a major problem in Pune, causing severe wastage of treated water. Events such as sudden bursting of water supply pipes do occur occasionally. Similarly, there have been incidences in the past in 1991, 1995, 1998, 2002 and most recently in 2018 when the wall of the Mutha Right Bank Canal has broken (Sakal Reporter, 28-09-2019). Canal wall breakage has caused wastage of large quantities of water and led to flooding in the nearby settlements. Apart from these incidences of failure of water supply pipes and canals, a major catastrophic event occurred in 1961, when the Panshet Dam broke and caused severe destruction in Pune.

Failure of the Panshet Dam in 1961

The failure of the Panshet Dam has left a permanent mark on the history of Pune and on its water infrastructures. Gogate (1988) has analysed the reasons for the failure of the dam in detail. In the 1950s, water supply from the Khadakwasla Dam proved insufficient to meet the increased water demand of Pune. Therefore, the State Government of Maharashtra undertook the construction of Panshet Dam in the upstream area of the Mutha River, above the Khadakwasla Dam in 1957. The planned year for the completion of the dam was 1962. However, the State Government preponed the year to 1961 and ordered the engineers to complete the dam before the State elections that were supposed to be held that year. The political motive of the State Government behind preponing the date of dam completion was to gain votes of the farmers who were the beneficiaries of the dam. Under work pressure of completing the dam before its scheduled time, the engineers made two major flaws in the design of the dam. Firstly, the spillway of the dam was kept 3m above the designed level. Secondly, the design of the conduit that was supposed to carry water from the Panshet reservoir to the Khadakwasla reservoir was changed at the last moment. Instead of constructing the conduit as a monolithic reinforced structure, it was constructed using precast concrete blocks (Gogate, 1988, pp.9-11).

The dam was completed in time on 5th July 1961. After its completion, it started raining continuously in the catchment area of the reservoir, and the reservoir was filled. On 12th July, there was a sudden downpour. The increased pressure of stored water broke the wall of the dam due to the faults in its design. The force of incoming water from the Panshet Dam broke the wall of the Khadakwasla Dam, releasing a large quantity of stored water into Pune. Within no time, there was a flood in Pune with water level reaching a height of 3m. The flood caused massive destruction, resulting in the death of 150 people and making about 95,000 people homeless (Gogate, 1988, pp. 12-14).

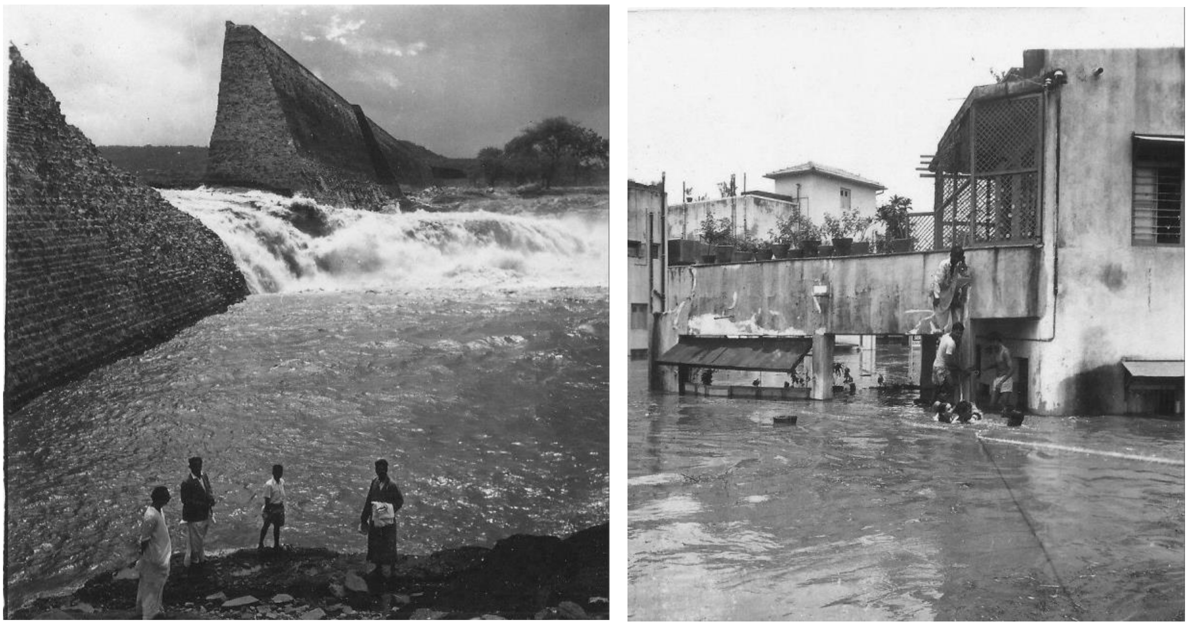


Figure 5.6: Images of the breaking of Panshet Dam and the flooding of Pune.
Source: Paranjape, 2011.

The failure of the Panshet Dam points out at two critical facts about centralised water infrastructure. Firstly, it points at the fact that political motives often drive and influence the construction of large dams. In this case, vote bank politics drew the construction of Panshet dam. The political agenda behind its creation was to earn the votes of dam beneficiaries ahead of the state election. This political motive created a pressure on the engineers to complete the dam ahead of its regular schedule due to which they committed structural errors in its design. Secondly, the event also points out how water infrastructure becomes critical due to the risk of failure. Large dams often create a false sense of security in the minds of people. Therefore, they remain unprepared for events of disaster and even occasional events when there is a release of a large quantity of water from the dams (Marsh and Kaufman, 2013, p.374).

5.4.3. Conclusion and the possible way ahead

This chapter aimed to examine the state of TWI during the British-Colonial and Post-Colonial Periods against the background of new water management practices. The observations from the discussion so far clearly show that there was a gradual decline in the use of TWI during the British-Colonial Period and an accelerated decline during the Post-Colonial Period. Some of the prominent reasons that caused this decline in the use of TWI are as follows:

Lack of patronage of the British-Colonial and Post-Colonial Governments to construct and maintain TWI

The survival of TWI has always depended on the patronage of rulers and wealthy persons. Without this patronage, common people alone could not construct and maintain TWI. However, both the colonial and post-colonial governments were unable to provide the required financial support to common people for continuing their tradition of building traditional water structures. Instead, driven by the motive of gaining maximum production from agriculture, the colonial and post-colonial governments encouraged people to switch from the use of traditional water structures to canals, wells and tubewells.

Interference in the traditional socio-cultural practices of people

The social relations and cultural practices prevalent in the traditional Indian communities played a critical role in the functioning of TWI. British governance policies and laws weakened these relations and practices. For instance, the British failed to understand the critical role of the village head as a link between the rulers and common people. In the traditional system, the village head could retain his position as long as he had the support of the common people and the rulers. His salary was proportionate to the total agricultural produce and the total revenue deposited by him in the government treasury. Therefore, he encouraged people to expand irrigation by constructing several small water structures. Once, the British started paying him a fixed salary; he became less concerned about increasing agricultural production and about the need to construct and maintain TWI. Similarly paying more for water-intensive crops such as sugarcane than traditional drought-resistant crops encouraged people to use canal water and neglect TWI.

The ideas about progress and modernity

The western-educated Indian nationalist and engineers driven by the ideas of modernity and progress concentrated on the construction of large dams alone and paid little attention towards traditional structures and systems of water management. Although the motive of such kind of top-down development was to let its benefits trickle down up to the poor farmers, in reality, it benefitted the wealthy farmers alone. Moreover, the real problem of small agricultural communities was that they were not able to continue with their traditional practices under the pressure of modernisation. As a result, many of the diverse, sustainable irrigation practices further declined in the post-colonial period. The convenience of modern water infrastructure to deliver the required quantity of water directly into the houses made many people give up the use of TWI.

Rapid demographic and spatial expansion

As discussed before, the government could do little to handle the rapid demographic and spatial growth of Pune, especially after the 1990s. The existing TWI could not have fulfilled the increased water demand, but it could have at least complimented the centralised water supply network. For instance, when the Panshet Dam failed, people could use water from the Katraj Nahar temporarily until the restoration of regular water supply. Furthermore, instead of concentrating on the expansion of the centralised piped water network alone, PMC could have worked at increasing the number of small water storage structures. However, it failed to understand the importance of TWI. Under the pressure of rapid urbanisation, the PMC filled and levelled most of the traditional water structures for generating more space for roads and housing.

These four reasons discussed so far caused a decline in the use of TWI in Pune, cutting down the possibility of accessing diverse water sources and increasing the risk of failure due to dependence on a single source of water, i.e. dam reservoirs. Simultaneously, mono-cropping and extensive irrigation during the colonial and post-colonial periods have made the soils infertile. Against the background of these problems that have emerged due to overdependence on modern technology and centralised water infrastructure, one can observe a prolonged change in the water management policies of the government. For instance, the 12th Five Year Plan (2012-2017) of India makes the following statement about water management,

Large dam projects have been the mainstay of the irrigation effort in the country. However, it is now recognized that there are definite limits to the role they can play in providing economically viable additional large water storage. […] Concern has also been expressed that the capture of so much water within the [river] basins has changed the regional climate, increasing the humidity and changing temperature regimes, aggravating saline groundwater intrusion, and putting at risk the delicate wetland and estuarine ecology which is important not only for aquatic habitats and fisheries but also for preventing shore erosion. (Planning Commission, 2013, p.145).

From the above statement, it is clear that at least at the policy level, the Government of India has realised the limitations of centralised water infrastructure. In line with the national policy and against the background of recurring droughts in Maharashtra, the State Government has undertaken the Mission titled 'Jalyukta Shivar', in 2014 (GOM, 5 December 2014). Under this mission, the State Government provides the necessary technical and financial support to villagers to undertake the construction of small irrigation structures. These policies by both

Central and State Governments are essential small steps in the direction of sustainable management of water resources in future.

The next chapter presents the main findings from the discussion so far and concludes the discussion on traditional water infrastructure by recommending different ways in which one could learn from traditional knowledge on water management and design the current water infrastructure in a sustainable way.

6. Discussion and Conclusion

This chapter concludes the discussion on Traditional Water Infrastructure (TWI) by summarising the main arguments made within this research. It presents the main findings, derives conclusions from them, and provides recommendations on the possible ways in which TWI could help in solving water-related problems in future. It suggests ways in which TWI could contribute towards enhancing the physical and socio-cultural environment of Pune and other similar places. The chapter ends by suggesting the possible outlook infrastructure research should follow in the future for seeking sustainable solutions to the prevailing water-related problems.

6.1. Summary

This research began with the discussion on the complexity of current water-related problems and the incapability of the technically driven approach in seeking solutions to these problems. It explained the limitation of this approach that considered water merely as a scarce economic good and failed to understand water as part of people's cultures, identities, worldviews, and religions. Such an approach worked well when water-related problems were simple and mainly about preventing water pollution and overcoming water scarcity. However, the main drawback of the approach was that it attempted to overcome water scarcity and pollution by controlling nature and neglecting the socio-ecological impacts of technology in the long-term.

Consequently, large-scale physical infrastructure consisting of dams, reservoirs, canals, and so on have displaced millions of people, altered the natural fluvial patterns, reduced sedimentation and affected biodiversity. Current water infrastructure manages to mask these harsh realities of water production from the people — distantly located water reservoirs and underground pipes cut-off our ties with the production process of water. From an architectural and design perspective, the current water infrastructure becomes an add-on entity superimposed as an invisible layer on the existing fabric of the urban and rural landscape. As a result, the current water infrastructure is unable to shape urban form and establish a human-water connection.

Against the background of emerging challenges such as climate change and rapid urbanisation, this research argued the necessity for shifting away from the technically driven approach. It proposed shifting towards an approach that seeks to find location-specific, contextual solutions to water-related problems. It presented the ideas of researchers who suggest the need for diversifying the water sources. For instance, Wong and Brown (2008) propose the need to imagine urban areas themselves as water catchment areas for reducing the dependency on external water sources. They also suggest the need to inculcate water sensitivity in society. Similarly, Domenech (2011) and Dicks (2014) discuss the importance of decentralising and diversifying water sources by working on methods such as rainwater harvesting and wastewater recycling. However, this research identified that these proposals suit the temperate conditions and cannot be transferred within their proposed format to tropical countries such as India.

Taking the case of India, the research argued that the physical conditions and rainfall pattern in India are different from countries such as Australia and England from where the proposals mentioned before emerge. Therefore, possible solutions towards adopting innovative water management in India must arise from its contextual and cultural specificity. In support of this argument, the research briefly discussed the different types of TWI such as podhis, baravs, nahars, talavs, and kunds designed by the traditional communities in accordance to the geography, topography, hydrology, climate, and ecology of different regions in India.

A literature overview of TWI highlighted three noticeable gaps. Firstly, the focus of the literature on TWI has been on its technical and managerial aspects and less on its spatial and architectural elements. Therefore, aspects such as the relation of water infrastructure with settlements, orientation, role in placemaking required further exploration. Secondly, the existing literature had a glaring lack concerning the operation of TWI in changed socio-cultural settings and exploring the possibility of adaptive reuse of the water structures. Lastly, regional imbalances in literature resulted in extensive coverage of only specific types of TWI such as stepped tanks and wells of Rajasthan and Gujarat, thereby omitting equally important types such as baravs, podhi, taakya, and nahars in Maharashtra.

These gaps led to the need for undertaking in-depth research on the TWI of Pune district in India. The research considered Pune district to represent the case of many metropolitan districts in India that have traversed along the technically driven path of water management irrespective of its failure to solve water-related problems and severe socio-ecological impacts. The research established the need for thinking beyond the technically driven approach of water management and the necessity of learning from the water conscious culture and TWI of Pune.

6.1.1. Restating research aim and objectives

For developing an in-depth understanding of TWI, the research employed the framework of Indian Cultural Landscape given by Singh (2013). It considered that through perpetual interaction with water, people developed perceptions about their geography, including water. Cultural practices, beliefs, oral traditions, and religious rituals exemplified these perceptions, while traditional water structures gave a physical form to these perceptions. Therefore, the research sought to first understand these water-related perceptions and ideas by decoding some of the beliefs, oral traditions, and religious texts and then examine how TWI reflects these perceptions. For doing so, the research considered a historical timeframe starting from 1700 B.C. for examining the different forms of TWI and their transition across time. Within this framework, the research aimed at *understanding the role and significance of Traditional Water Infrastructure (TWI) as emerging from the cultural complex of Pune in solving its water-related problems.*

Due to the broadness of the research aim, it was split into four research objectives. The first objective was to understand the conceptualisation of water in the ancient culture of Pune. It sought to find the water-related concepts, ideas, beliefs and values and the way they have influenced people's practices of constructing water infrastructure. The second objective sought to understand the working of TWI within the physical and cultural context of Pune. Herein, it explained the key principles behind designing of TWI and their role in making TWI multi-functional. The third objective aimed at investigating the reasons for the decline of TWI. It investigated the way British-Colonial and Post-Colonial policies of water management affected the TWI. The last objective sought to suggest possible ways of learning from TWI. This chapter attempts to achieve this last objective. These four objectives have been the basis for the structuring of the four chapters following the Introduction Chapter. The following section expands upon the key findings and summary mentioned at the end of previous chapters.

6.2. Findings and Conclusion

6.2.1. Criticality across different periods

From a cultural and historical perspective, it is necessary to trace how certain cultures have considered particular services as critical due to collective preferences (Vleuten et al., 2013, p.13). A significant observation that emerges from the discussion so far is that in Pune and India in general, people have traditionally ascribed criticality more to water than water infrastructure. As discussed in Chapter 2, the limited availability of fresh water due to the monsoon pattern and nature of rivers made water a critical natural resource. The basic sustenance of people and agriculture depended on a good and timely monsoon. A fluctuation in the timing, as well as quantity of rainfall, caused droughts and floods affecting the livelihood of people. Therefore, criticality emerges largely from the 'nature of the Indian monsoon'. Traditional water systems thus acted as preparedness strategies for storing the rainwater for year-round availability. Since these systems and structures were diverse and decentralised, the fear of failure of these systems was less in comparison to the failure of monsoon. Nonetheless, the criticality of water was built upon the underlying notion of 'need for action' or 'obligation to act'. As a result, ancient religious texts such as Krishi Parashar (discussed in Chapter 2) mention how farmers should remain prepared for the rainfall uncertainty.

Also, water and water infrastructure were critical mainly because of the hydraulic relation they created between the rulers and ordinary people. Agriculture was the primary source of revenue for the rulers, as seen in Chapters 2 and 4. As agriculture was largely rain-fed, it was vulnerable to droughts and floods. For reducing this vulnerability, the rulers provided the necessary financial support for constructing various water structures and bringing more land under irrigation. Financing the construction of water structure also enabled the Deccan Sultanate rulers to establish their power in Pune and the surrounding region. The rulers often urged rich people to finance the construction of water structures so that they did not have to bear the entire burden of the loss , but instead take a calculated risk of possible loss in investment.

During the British Colonial Period, we can observe that for the British, water infrastructure became more critical rather than water itself because of their substantial financial investment in the construction of dams and canals. Since earning profit from the irrigation works was the main objective of the British, they categorised all the works from which they could earn profit as 'productive works'. However, the British soon realised that although earning profit was necessary, ensuring that people had access to irrigation facilities during droughts is equally essential if they wanted to prevent people's unrest and continue their rule in India. Therefore, they undertook the construction of dams and canals, where earning profit was less important than protecting agriculture from droughts (Beinart and Hughes, 2009, p.134). They categorised such works as 'protective works'. Thus, in the British Colonial Period, economics and power legitimacy largely defined the criticality of water infrastructure.

After independence, water infrastructure became critical for another reason. The Indian nationalists believed that for advancing along the path of progress and development, it was necessary to have an agricultural surplus and increased trade. Therefore, water infrastructure became critical for traversing along the path of scientific growth and development. As the criticality of water infrastructure superseded over criticality of water, the traditional value about water and the knowledge of conserving water through sustainable ways gradually faded in the background. Until today, water management largely considers water infrastructure critical for the economic well-being, and agricultural and industrial growth.

To conclude, a cultural and historical overview is essential to understand where the criticality of infrastructures emerges from, during different periods of history. Such an understanding facilitates in identifying the precise problems of water infrastructure and finding appropriate solutions in the form of corrective actions to those problems. The next section presents the findings highlighting the traditional knowledge embedded in culture and its significance in the sustainable use of water resources.

6.2.2. Value of traditional knowledge in the sustainable use of water resources

Collective perceptions and close interaction of people with their surroundings in India shaped their relationship with nature (Singh, 2017b, p.1). Similar to most pre-industrial cultures, the Hindu culture sees humans as a part of nature and the larger ecosystem. There is a symbiotic relationship between humans and nature. A separation does not exist between humans and non-human entities (Berkes et al., 1995, p.285). An individual's identity is part of the collective identity. This worldview reflects itself in the traditional knowledge about water that developed within the interaction of ancient Indians with the climate, monsoon pattern and various water bodies, including rivers. The discussion in Chapter 2 shows that through prolonged observation, ancient Indians knew about the flooding pattern of rivers, ecological importance of forests around river sources, seasonal trends, amount of rainfall received at different places and so on. However, this ancient knowledge is not explicit and often embedded in cultural practices, beliefs, myths and rituals. Therefore, one needs to decipher these cultural aspects for understanding the underlying wisdom and values related to water.

For instance, the cultural practice of considering most of the rivers as feminine and worshipping them as mother goddesses may seem irrational to many in the present context. However, after close examination, we realise that the practice made sense as the survival of ancient people depended on rivers for water, food (agriculture and fish) and transportation. They had attuned their life to the natural flooding pattern of the rivers, and hence they worshipped both their life-nourishing as well as devastating properties. Worshipping rivers does not mean that they did not attempt to alter the natural fluvial pattern of rivers. They had to divert river courses, build dams and canals. However, the values and cultural practices often (not always) ensured that such alterations were light and did not destroy the existing water balance (Shiva, 2008, p. 500).

Similarly, certain beliefs and social restraints, which some may consider as superstitions, have enabled ancient communities to utilise resources prudently, conserve them and maintain the ecological balance (Berkes et al., 1995). For instance, in the case of Devrais, the belief of particular forests belonging to God and enforcing the social restrain of not utilising any of their resources may seem unusual to an outsider. Nonetheless, communities who were part of the larger ecosystem developed such belief knowing the ecological value of such forests as bio reserves around the source of rivers. They knew that protecting river sources is essential for preventing downstream pollution of rivers. Religious taboos or social restraints were a way of imbibing this wisdom in the community without questioning. Herein, the collective interest of the community and maintenance of overall ecosystem was more critical than individual self-interest (ibid). In addition to beliefs and social restrains, the encoding of rules within religious rituals assured that they are not forgotten by the members of the community (Berkes et al., 2000, p.1258).

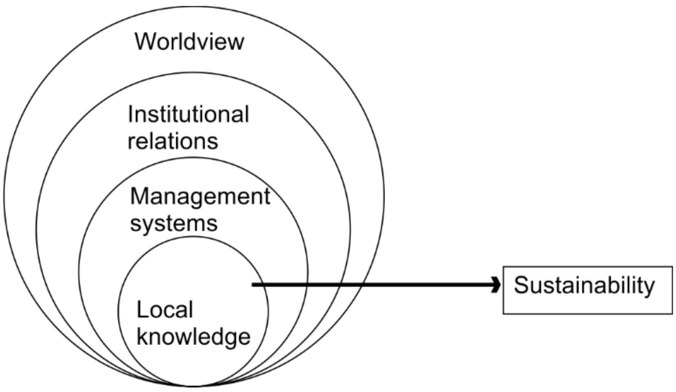


Figure 6.1: Use of local knowledge in sustainability.
Source: Adapted from Singh, 2017a, p.16.

To conclude, the knowledge embedded in various cultural practices, beliefs, social restrains and religious rituals could be useful in the sustainable use of water resources and developing resilience to future water-related uncertainties. This does not mean that all these aspects forming a part of the cultural complex would be relevant and would work today. Nonetheless, one must be open to learning from the traditional knowledge of a particular culture as modern science may provide the necessary tools for enhancing sustainability and resource efficiency, but it may not provide the ethical values that enable us to reflect upon our actions (Valdesuso, 2011, p.8). Traditional knowledge can often provide the ethical values that help us to question our acts and interference in natural processes. Imbibing moral and ethical values in society is necessary for sustainable use of water resources.

Apart from being ethical, traditional knowledge related to water has developed and evolved over a long period through direct human interaction with the natural world. Therefore, often, it has an inherent understanding that environmental conditions always change and there is a limitation to the extent humans can control nature and predict future problems. As a result, unlike modern science that attempts to make water infrastructure resilient to future uncertainties through control and use of technology, traditional knowledge accepts uncertainties and attempts at making society resilient through social learning (Berkes et al., 2000, p. 1260). Thus, traditional knowledge must support scientific knowledge for facing water-related challenges in future. The next set of findings present the key characteristics of TWI and their significance in the present context.

6.2.3. TWI: location specificity, visibility, detailing, multi-functionality and people's participation

People's conceptualisation of water gained material form through traditional water infrastructure. This material form was diverse based upon the terrain, climate, geology and hydrology of the place. A strong connection with the local conditions is a common feature of most traditional water structures (Jacob, 2013, p.3). This feature gave rise to diverse forms of water structures all over India. Within Pune itself, there were diverse water storage structures and systems such as the podhis, taakya, barav, kunds, talavs and nahars. In addition, people used different devices such as the rahat, rahat gadge and the mot for lifting water. All these diverse structures and systems are site-specific. For instance, the baravs at Loni Bhapkar and Manchar are located at places where the groundwater was available at a depth of not more than 10 metres. Similarly, talavs at Vadaki and Jejuri are located in a shallow locus where rainwater and surface runoff could easily accumulate. If anyone attempts to copy these structures without understanding their location specificity, they will fail. This location specificity makes TWI sustainable due to its smallest ecological footprint (Jacob, 2013, p.3).

Another feature of TWI is that it allowed people to see, hear, touch and experience water is equally important in addition to its location specificity. The visibility of water and its presence within or near the settlements created a strong bond between people and water. The steps of kunds and barav enabled people to monitor the water level and adjust their water consumption according to the availability of water (Mishra, 1993). The design of the kunds at Ranje was such that people could set priorities for their water usage – first for drinking, then for bathing, afterwards for cleaning and washing utensils, and lastly for agriculture. This design sensitivity is difficult to achieve in centralised water infrastructure. Firstly, with distantly located dams and underground pipes, people can barely see the water. Even in water tankers, people see the container but not the water stored inside it. In the case of tubewells, it is neither possible to see groundwater nor estimate its available quantity. As people rarely see natural water themselves, it becomes difficult for them to realise the finite availability of water in nature.

Secondly, modern water management strategy in India works on mathematical calculations. It calculates the total quantity of water required for the entire population based on the thumb rule of providing 150 litres per capita per day.[72] Such a method of calculating water requirement seldom works in reality. People rarely have equitable access to water. On most occasions, certain areas are overserved while certain areas remain underserved. When the population increases and demand exceeds supply, planners search for new sources of water. Such a calculation lacks the flexibility of increasing and decreasing supply as per seasonal change and availability. Moreover, in such a system, people seldom share the responsibility of keeping a check on their consumption pattern as per the availability of water. Thus, proximity to natural water sources and the visibility of water are important factors for creating water consciousness in the society.

Along with the visibility of TWI, its architectural detailing and even aesthetics ensured that water remains clean and pollution-free. The construction of a parapet wall around baravs and kunds blocked the entry and mixing of surface-runoff into the clean water. Similarly, the architectural detailing of having a channel in the form of a tile-drop around the hauds helped to redirect the spilt water back towards them, thereby preventing even the slightest wastage. Even the aesthetic elements such as the figurative deities within the niches of the parapet wall had a symbolic meaning. They represented the connection of the physical manifestations with meta-physical manifestations (Hegewald, 2002, pp.126-128). The practice of placing deities in niches was a way of highlighting the sanctity of the water structure as well as marking a kind of sacred realm where people would not indulge in any acts of water pollution.

Lastly, as the people built TWI through their collective effort and participation, they had a sense of ownership and belonging towards it. For this reason, they respected their water structures, protected them and used water cautiously. This does not mean there would have been no

[72] The Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines by the Ministry of Urban Development propose that megacities having piped water supply and sewage system should receive a maximum water supply of 150 litres per capita per day (Ministry of Urban Development, GOI, 2015, p.315).

conflicts or free ridership, but as Ostrom (1992) mentions, small communities function based on 'rules in place'. These rules differ from formal laws in the sense that they are not written down. People in the community are aware and follow them in their daily practices. Since everyone knows each other, people follow the rules out of the fear of inviting community anger. These rules are invisible to an outsider (Ostrom, 1992, p.20). Today, the biggest change that has occurred in society is that there is no involvement of people in the construction or maintenance of water infrastructure. Paying water tax alone does not make people responsible for using water cautiously. By paying taxes, many people develop a 'government will provide' attitude and shed away their responsibility (Jacob, 2013, p. 5). Simply increasing taxes also does not make people responsible. Those having the capacity of paying the taxes continue being irresponsible while the poor have to suffer. Thus, water management strategies should work out innovative ways of inviting people's participation in water infrastructure construction and maintenance for instigating water consciousness in society.

To conclude, location specificity, visibility, architectural detailing, multi-functionality and people's participation are the key characteristics of TWI that stand out from the discussion in Chapters 3 and 4. It may be difficult to achieve these characteristics in the current centralised water infrastructure. However, even slight alterations that could bring in these characteristics to a little extent may bring about a significant change in people's attitude towards water. If this is difficult, at least the design of water infrastructure in future could aim to bring in these characteristics. They are essential for the sustainability of water resources. The recommendations mentioned later give some ideas about the possibility of learning from TWI and imagining water infrastructure differently.

In spite of the characteristics of TWI mentioned earlier, the number of traditional water structures declined during the British Colonial and Post-colonial period severely. The next set of findings highlight the reasons for this phenomenon.

6.2.4. The decline of TWI: clash of motives, lack of understanding of cultural context and rapid demographic and physical changes

Conservation of water, especially precious rainwater for community well-being with minimum interference in the natural hydrological cycle was the primary motive with which people designed TWI. The exploitation of water resources for monetary yields was never the primary objective. Although the Hindu and Deccan Sultanate rulers encouraged the construction of TWI for earning revenue, they also granted concessions in taxes and remissions in loans to poor farmers in case of natural calamities such as droughts (Khobrekar, 2006, pp.555-559). Ensuring the overall welfare of the subjects was more or less their prime objective for preventing any outrage from the people. On the contrary, for the British, India's resources, including water, were means for earning monetary yields and profits through their systematic exploitation (Narain, 2006, para.24-27). For this reason, the British employed modern technology of constructing dams and laying canals for intensifying irrigation, increasing agricultural production, and earning maximum profits through trade. Since traditional techniques and water structures due to their decentralised nature would not have fulfilled their motive, they built infrastructures such as dams that allowed them to have centralised control and management. In the process, they discontinued the practice of constructing and maintaining TWI.

Although exploitation of water resources may not have been the motive of Indian western-educated nationalists, their vision of projecting India as a modern and progressive nation invariably demanded the exploitation of water resources to the fullest. Therefore, they continued the British trajectory of constructing large dams for blocking rivers and using modern devices such as tubewells for extracting groundwater. Thus, even the western-educated nationalist failed to understand the importance of TWI and neglected it systematically. As seen before, TWI could survive only with the financial support of rulers and patrons. With both the British and Indian Governments disinterested in financing TWI, traditional communities had to give up the construction and maintenance of TWI (Narain, 2006, para.29).

However, the exploitive motive of the British was not the only reason why there was a decline in TWI, as argued by many researchers. As discussed in Chapter 5, the East India Company did attempt to maintain traditional water structures. However, they failed to understand that TWI could operate only within the traditional socio-cultural, political and economic fabric of India. The British coming from a different contextual setup were unable to understand these aspects. Firstly, the operation of TWI was based on sharing, negotiation and mutual dependence (Jacob, 2013, p.4). Hydraulic relations tied the common people, the village head, the wealthy, and the rulers to each other. There were occasional conflicts. Local politics, the priority of water access to the upper castes and caste discrimination did exist. However, incidences of denying water access to any particular person or group were rare (ibid). Moreover, most of the times, the rulers kept a check on such practices. The interference of the British in the social fabric by employing bonded labourers in maintaining TWI relieved the common people of their duty of maintaining the water structures periodically. They systematically neglected water structures due to a change in ideology and use. Secondly, the British encouraged farmers to grow sugarcane for earning profits. Sugarcane being a water-intensive crop, demanded a large quantity of water which TWI could not provide. Therefore, they switched to the use of canal water.[73] Thus, such interventions by the British were equally responsible for the decline in TWI, highlighting the complexity of systematic neglect.

Lastly and most importantly, Indian cities such as Pune experienced rapid demographic and spatial expansion after independence. Within the last seven decades, Pune's population increased six-fold from 0.48 million in 1950 to 3.1 million in 2011 (BES, GOM, 1958, p.5; DCO,

[73] Chapter 5 discusses this phenomenon in detail.

2014, p.22). At the same time, there was a two-fold increase in the area under municipal jurisdiction from 139 sq.km to 331 sq.km (Mundhe and Jaybhaye, 2017, p.34,47). It was difficult for the Municipal Corporation to cope up with such a rapid increase in population. An easy and quick way of meeting the water requirement of such a large population was by expanding the centralised water supply network. Wherever the Municipal water network could not reach to people, they extracted groundwater by tubewells. The convenience of using tap water and groundwater in comparison to water obtained by using traditional means also prompted people to give up TWI (Hegewald, 2002, p.214). When tap water came right up to their household, it was much more convenient to fill water within their household rather than going up to the traditional water structures to fetch water. Similarly, since tubewells were within the land parcels of individuals, they had private ownership over them and could extract the required quantity of water at their free will. Thus, convenience and ease of access due to networked ideal were equally responsible for the decline in TWI.

To conclude, purposeful neglect by the British was not the only reason for the decline of TWI. It was one of the reason in addition to their inability to understand the complex socio-cultural, political and economic fabric existing in traditional communities. Furthermore, the water management policy of the western-educated Indian nationalists that was a direct outcome of their fascination towards modernity was equally responsible for the decline of TWI. Similarly, the rapid change in the demographic and physical conditions of Indian cities such as Pune prompted the government to adopt easy and quick solutions to the problem of water scarcity by building and expanding centralised water infrastructure. In doing so, the government did not consider the long-term consequences of their solutions that further aggravated the water-related problems.

To summarise, the three sets of findings and conclusions discussed above clearly indicate that water infrastructure design and management in the future would be sustainable only if the traditional values that created water sensitivity resurface in the society. As TWI is often the manifestation of these values, understanding its key characteristics could help to reimagine the design and management of current water infrastructure differently. At the same time, it is critical to question the ideas of modernity and progress that consider water as an economic commodity and attempt to exploit it to the fullest. As a result, design and management of water infrastructure in future must aim at re-establishing the balance of natural hydrological cycle and aim to inculcate water consciousness in the society. Based on these aspects, the following section presents a few recommendations on the possibilities of learning from TWI and various ways in which it could minimise the current water-related problems.

6.3. Recommendations

6.3.1. Resurfacing TWI for building resilience through diversity

The criticality of current water infrastructure is evoking researchers to seek solutions for making it more resilient in the future against the background of climate change, rapid urbanisation and finite availability of freshwater sources. Similarly, the flexibility and adaptability of current water infrastructure to changing conditions of climate and demography is low (Schramm and Felmeden, 2012, p.178). With changing climatic conditions, centralised water infrastructure is always at a high risk of failure. The source of most centralised water supply systems is a single large reservoir. Very low precipitation in the catchment area of the reservoir could cause serious water scarcity while very high rainfall in the catchment areas requiring the release of excess water from reservoirs can cause the problem of downstream flooding.

At present, Cape Town is constantly under the threat of experiencing a 'Day Zero'. In 2015, Cape Town experienced once in a thousand-year drought in 2015 and hence the water storage from its reservoirs diminished (Arcanjo, 2018, p.1). Therefore, the Government of Cape Town had imagined 16 April 2018 to be a day zero when the level of stored water in the dams would fall below 13%, and it would shut down the household water supply. People were then supposed to cue up on public stand posts for obtaining 25 litres of water per day (ibid). However, with extreme restrictions on water usage, efficient agricultural practices, the Government managed to postpone Day Zero. Nonetheless, the possibility of a Day Zero arriving shortly continues to bother the government and people of Cape Town. Similarly, Indian cities such as Delhi and Bangalore also face the threat of a Day Zero in 2025 if they do not alter their water consumption pattern. (Matto, 2019).

Similar to the climatic conditions, demographic conditions change quite rapidly, thereby affecting water infrastructure. For instance, on the one hand, the shrinking population in some regions of Germany has resulted in underutilization of centralized water infrastructure in those areas (Schramm and Felmeden, 2012, p.178) On the other hand, high population growth in regions of China has increased the pressure on centralized water infrastructure and increased the risk of insufficient water supply. Thus, urban areas have become extremely vulnerable to fluctuating water quantities due to their overdependence on centralised water infrastructure.

For increasing the resilience of urban areas to water scarcity, it is necessary to reduce their dependence on a single source of water, i.e. mainly large storage reservoirs. Instead, they need to have access to multiple smaller sources of water. Schramm and Felmeden (2012) recommend the option of having the flexibility of accessing a 'portfolio' of water sources for making water infrastructure more resilient. They point out that instead of carrying out an incremental improvement of the centralised water infrastructure, identifying and accessing different decentralised smaller sources of water needs to be the future path towards sustainable water management (Schramm and Felmeden, 2012, p.179). When a place obtains water from diverse sources, the risk of a complete water supply failure during natural calamities such as droughts is low. Having access to multiple water sources means that even if few of the sources fail to store water, there would be some possibility of obtaining water from other sources. The chances of a complete failure of the water supply system would be extremely rare. In short, having access to diverse water sources within urban areas can make them more resilient to climatic and demographic changes in the future.

In the case of Pune, the water supply of the city and its peripheral areas is mostly dependent on the four reservoirs of Khadakwasla, Panshet, Temghar, and Varasgaon all located about 20 km to the south-west of Pune (GOM, 2012, p.86). All these reservoirs store water from the same water catchment area of the Mutha River. As mentioned before, if in a particular year there is a severe deficit in the average annual rainfall in this catchment area, it would lead to severe water scarcity in Pune. Incidences in the past have shown that even a marginal deficit in the average annual rainfall in the water catchment area of these four reservoirs causes water scarcity during the peak summer months of April and May before the arrival of the monsoon in June. Furthermore, as already discussed in Chapter 5, water distribution losses to the extent of 35% cause wastage of water. If these challenges were to be solved by the conventional method of finding a new source of water and at the same time upgrading the existing centralised water infrastructure, the PMC would incur a total expenditure of Rs 27 billion as per an estimate prepared in 2014 (PMC, 2014, p.183).

Instead of incurring such a large expenditure on expanding the current water infrastructure, it would be worthwhile to explore the possibility of learning from TWI and constructing smaller storage reservoirs that complement the centralised water infrastructure. This can be done in two ways. First, by repairing the existing TWI wherever possible and maintaining them appropriately in the future. The restoring would especially benefit the fringe and rural areas of Pune. As per the Agricultural Census Report 2010-11, irrigation by such traditional tanks and small reservoirs accounted for 3% and by other sources (sources other than canals, wells, tubewells, and tanks) to 26% (Agricultural Census, 2015, Table 5A, Pune District) There is a need to identify which are these other sources of irrigation and understand their characteristics. Some of them could be traditional methods of harvesting water. Increasing the area irrigated by TWI can reduce the burden on the centralised water infrastructure to a little extent as well as prevent over-exploitation of groundwater.

A second alternative would be to learn from the existing TWI and encourage rural people to construct similar low-cost structures in the future. They would be sustainable both economically as well as ecologically. Small check dams and reservoirs cost less in comparison to large dams. Moreover, as proven scientifically by Agarwal et al. (2001) smaller the size of water catchment, higher is the surface-runoff collected. As the size of water catchment increases, they collect little surface-runoff, as a significant part of it is lost in puddles and depressions, in soil, and through evaporation Thus, ten small dams with a catchment of 1 ha each would together collect more water than one large dam with a catchment of 10 ha (Agarwal et al., 2001, pp. xviii-xix).

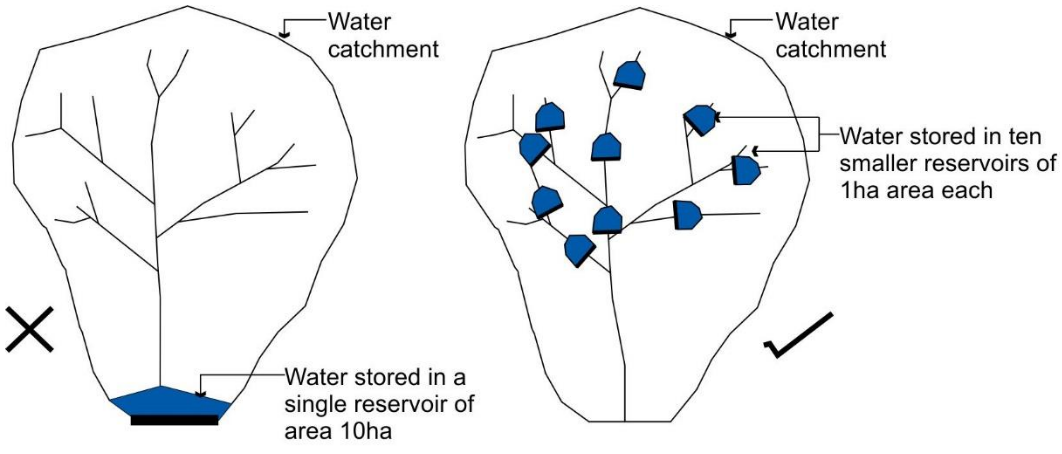


Figure 6.2: Sketch showing the importance of small water reservoirs.
Source: Adapted from Agarwal et al., 2001, p.xxi.

The Chief Minister of Maharashtra undertook an encouraging step in 2014 to realise the above two measures into reality by initiating the mission *Jalyukta Shivar*. The mission aims to reduce Maharashtra State's vulnerability to droughts gradually by providing the necessary support to the rural people for undertaking the construction of new small-scale water harvesting structures as well as repairing the already existing ones (GOM, 5 December 2014, p.3). Under this mission, the Government of Maharashtra provided funds worth Rs 4400 million to the rural people in Pune for constructing and repairing small-scale water harvesting structures during 2015-2018 (DSA, 2018, pp.1-10). These structures mainly included tanks, ponds, earthen check dams, water recharge pits, and so on. This work caused an improvement in the groundwater table by 1 m to 2m.[74]

Although the mission Jalyukta Shivar is a good initiative by the Maharashtra Government towards decentralisation of water infrastructure, it has some shortcomings. For instance, hydrologist Phadnis (2018) observes that most of the work undertaken by rural people was in the form of deepening the water storage structures by removing the accumulated silt. Therefore, the water storage capacity of these structures increased, but the stored water was not necessarily well managed and distributed. He further suggests that often the new water storage structures constructed do not necessarily take the natural gradient of the terrain and topography into account[75]. Herein, TWI can provide important clues about site selection and effective measures of distributing the stored water. As already seen in the findings, the ancient communities built TWI through close observation of the natural terrain and climate patterns.

[74] The author obtained this information from the District Superintendent of Agriculture through a Right to Information Application filed under the Right to Information (RTI) Act-2006, on 01-10-2018.
[75] Based on the interview of Phadnis taken on 20-02-2018. Refer appendix for details.

A careful study of TWI can provide valuable guidelines for constructing new sustainable water storage structures in future.

Similar to Pune, innumerable places in India have their own TWI. If the different state governments provide the necessary support to the people for maintaining their TWI, it would add to the diversity of water infrastructure in India. Having access to diverse water sources rather than a single source would better equip different urban and rural areas to face the climatic and demographic challenges of the future.

6.3.2. Achieving Water Sensitive Urban Design (WSUD) through TWI

Rapid urbanisation has severely altered the natural hydrological cycle of precipitation, infiltration, surface runoff, and evaporation. Urban areas have extensive paved surfaces, sometimes even to the extent of 90%, which disallow water to infiltrate into the ground (Hoyer et al., 2011, pp.9-10). At the same time, conventional drainage system rapidly collects and discharges stormwater back to water bodies leaving no time for evaporation. Conventional drainage prevents groundwater recharge and pollutes the receiving rivers or water bodies. Moreover, it causes the wastage of precious water resource. With climate change, events of cloudburst and sudden downpour are becoming common. In case of such sudden heavy downpour in urban areas, neither can water infiltrate into the ground due to extensive paved surfaces, nor does the stormwater drainage system discharge it quickly enough due to its limited capacity. Therefore, many urban areas face the threat of flooding. Water Sensitive Urban Design (WSUD) seeks to find sustainable ways of effectively managing urban stormwater.

WSUD attempts to incorporate sustainability principles into urban water management. It considers the total urban water cycle. By adopting methods such as rainwater harvesting, stormwater harvesting and greywater recycling, it attempts at reducing the impact of urban development on ecological and hydrological processes (Hoyer et al., 2011, p.11,18) It integrates the disciplines of water management, urban design and landscape planning. In technical reclamation technologies, the processes of transport and treatment of stormwater and greywater remain invisible and happen away from settlements. In the case of WSUD, the stormwater and greywater are collected and treated on-site with the help of natural landscape and are visible to the people. The term WSUD originated in Australia. It is known by different terms in other countries. In the USA, it is known as Low Impact Development (LID) or Green Infrastructure (GI); in the UK as Sustainable Urban Drainage Systems (SUDS). In Europe, it is part of Best Management practices (BMPs). In Germany, it is part of Decentralized Rainwater/Stormwater management (DRWM). WSUD is globally also sometimes referred to as Integrated Urban Resource Water Management (IURWM), which considers management not only of stormwater but also of overall urban water (Hoyer et al., 2011, p.20).

In India, WSUD plays a critical role in reducing surface runoff, thereby reducing the load on stormwater sewers. Depending on the amount of rainfall and the run-off coefficient, harvesting rainwater into appropriate water storage structures can reduce the surface run-off in the range of 23% to 48% (Sapkota et al., 2015,p.159). Utilising this harvested rainwater for domestic purposes after suitable treatment can significantly reduce the dependency on centralised water infrastructure. Moreover, it is 5 to 10 times cheaper than costly solutions such as seawater desalination (Gehrmann, 2018. p.225). Furthermore, the embeddedness of WSUD into the settlement and landscape design enables people to see and experience natural water ecosystems, unlike conventional stormwater drainage system where water flows remain mostly invisible.

The findings from this research clearly show that the various talavs around Pune followed the principle of WSUD. The Mastani Talav at Vadaki, the talavs built by Peshwe and Holkar at Jejuri, the Katraj Talav in Pune are critical rainwater storage structures. If the government or private institutions could provide the necessary financial support to residents for repairing and maintaining these talavs, they would have the potential to function as urban sponges. Rainwater stored in these talavs could significantly reduce the excessive surface runoff and reduce the vulnerability of the flood-prone settlements.

The two recommendations given so far about the possible use of TWI are mainly from a water infrastructure point of view. Both of them mainly recognise the criticality of water infrastructure and attempt to give solutions in making it more resilient to face the future challenges of climate change and urbanisation. Both these recommendations primarily consider the role of TWI in enhancing water supply. However, apart from its utilitarian function in the future, TWI could play a much larger role in improving the urban environment of different places.

6.3.3. Improving the urban environment through TWI

Cities in India and Asia are sprawling at a rapid rate. As mentioned before, within 7 decades, the municipal area of Pune has more than doubled from 139 sq.km in 1950 to 331 sq.km in 2019 within seven decades. Rapid urbanisation poses a severe threat to various urban and peri-urban water bodies that struggle to survive the pressure of being filled, levelled and converted to sites for constructing new housing projects. Currently, the Pashan Lake with an area of 62.2ha, Katraj Upper Talav with an area of 7.2ha and Katraj Lower Lake with an area of 18.6 ha, and a few other smaller lakes are the last surviving water bodies in Pune (PMC, 2018). However, a neglect from the Municipal Corporation and people along with the release of sewage water and dumping of wastes are polluting these water bodies. For instance, mixing of sewage water into the Katraj Talavs has increased the number of dissolved hydroxides, carbonates and bicarbonates which in turn has increased the alkalinity of their water (Khare and Jadhav, 2007, p.297). They are covered with water hyacinth that prevents the growth of native aquatic plants and depletes the level of dissolved oxygen from the talavs rapidly.

The Municipal Corporation and the citizens of Pune need to keep a check on the pollution of these urban water bodies. Often such small urban water bodies are extremely sensitive and vulnerable to anthropogenic disturbances and protecting them is critical, as they are thriving places for freshwater biodiversity (Biggs et al., 2017, p.3). Many of the talavs and other lakes in and around Pune are habitats for migratory birds. Koparde and Raote (2016) have recorded the presence of 177 different bird species near the water bodies in and around Pune. Out of these 177 species, four species are globally threatened species (Koparde and Raote, 2016,p.51). Therefore, the PMC should identify all such water bodies in and around Pune, including traditional and colonial water storage ponds, lakes and reservoirs. After identifying such water bodies, it is necessary to mark them on the development plan of Pune and set out regulations for their protection and conservation.

Conservation of TWI is difficult and challenging, requiring active public awareness and participation. However, it is not an impossible task. An excellent example of conserving urban water bodies through the collaborative effort of the municipal corporation and citizen group is the case of Lakaki Lake in Model Colony area of Pune. Although the lake is not a traditional water structure, it is more than a century-old abandoned stone quarry that stored rainwater and turned itself into a lake and habitat for diverse flora and fauna (Bhan, 2008,p.64). Natural springs maintained the water level in the lake. In 1985, the Corporation had proposed to fill up the quarry and develop an educational institute on its six-acre area. However, the residents from the area opposed this proposal. They consulted two botanists Meera David and S.B. David who undertook a detailed study of the lake and found diverse life forms. Also, they found a special species of fish known as *Garubusia affinis* that ate the mosquito larvae from the water and prevented their breeding in the lake.

Figure 6.3: View of the restored Lakaki Lake, Model Colony, Pune.
Source: www.punerealestate.com, 31-07-2019.

Figure 6.4: Plan of Lakaki Lake in Model Colony, Pune.
Source: Adapted from www.ravindrabhan.com, 23-07-2019.
Google Earth Pro 7.3.2.5491, 23-01-2019. Model Colony Lake.

Based on their findings, the citizens submitted a proposal to the Corporation demanding the protection of the lake as an ecological reserve. They formed a citizens group, obtained the support of eminent personalities in Pune, and together compelled the Corporation to cancel its proposal of filling the lake and developing an educational complex. The citizen group, together with the support of Indian National Trust for Art and Cultural Heritage (INTACH), hired renowned Indian Landscape Architect Ravindra Bhan for developing the area around the lake, ensuring minimum human intervention. Upon completion of the project in 2001, the lake has been conserved as an eco-sensitive park within an urban settlement (ibid). In short, vigilant citizens play an important role in ensuring that the City Corporation takes the right development decisions which benefit the larger city environment.

In addition to its ecological role, TWI also helps in maintaining a comfortable temperature within urban areas through evaporative cooling. Several gardens having hauds and talavs once dotted the landscape of Pune. These water structures with shaded trees around them favoured the microclimate of Pune. However, as already seen in Chapter 5, the increasing pressure of urbanisation destroyed most of these traditional water structures. Especially within the past three decades, an increase in the network of roads, paved surfaces and high density of housing have caused a gradual increase in the night temperatures of many Indian cities including Pune. This rise is due to the trapping of short wave radiation in most cities due to rise in multi-storied buildings. The annual mean temperature of 12 major cities in India, including Pune during 1971-2013 has increased at the rate of 0.18°C per decade (Kothawale et al., 2016, pp.387-392).

As a remedy to this heating island effect, Manteghi et al. (2015) suggest that having well-shaded water bodies within urban areas could have a positive cooling effect on the urban microclimate. They observe that the temperature of a well-shaded water body is usually lower than the surrounding urban environment by 2°C to 6°C (Manteghi et al., 2015,p.2). Therefore, evaporative cooling from such water bodies is one of the methods of passive cooling in urban areas. Nonetheless, such water bodies must have enough tree cover around them; otherwise, if their temperature is higher than the surrounding, they have a heating effect on the microclimate especially during the late evening and nighttime. For this reason, most of the wells, hauds and talavs were located within gardens and orchards shaded by dense tree cover. Even today, if adequate tree cover is present along the edges of the Katraj Talavs in Pune, and the Peshwe and Holkar Talavs in Jejuri, they could have a positive cooling effect on the microclimate.

While improving the urban environment, the precincts of TWI could serve as places for informal gathering and social interaction and thereby could play an important role in placemaking. Moreover, TWI offers the possibility of learning about the act of public place-making and designing similar places in the contemporary urban context.

6.3.4. Place-making through TWI

TWI in Pune and India has not only been designed for the utilitarian purpose of diverting, capturing or storing water but also for celebrating the presence of water in settlements. TWI such as wells, stepwells, talavs and hauds served as important landmarks, pause points, meeting destinations and places of interaction for many people. Since, it was usually the women who fetched water, the water structures and their precincts often functioned as distinct feminine places for social integration. Meeting and interacting with each other helped the women to escape from the shackles of a patriarchal system temporarily (Jain-Neubauer, 2016, p.8). Similarly, some of the hauds in Pune were daily meeting points for the men in the society who gathered every morning for taking a bath. Apart from serving as places for social interaction, kunds, baravs and tanks located within temples were places for performing religious rituals.

Although people's lifestyle and religious values have changed, many people, especially rural women, continue to meet each other daily at the water structures such as the Holkar and Peshwe talavs as observed during the field research. Similarly, bathing and performance of rituals happen at some of the kunds such as the ones within the Ranjeshwar Temple at Ranje. Many people still visit temples in both the rural and urban areas. In addition to the temples mentioned in the earlier chapters, few other temples such as the Tapaneshwar Temple in Manchar, the Shiva temple in Jejuri contain beautiful water structures that lie in a neglected state. It is my common observation during field research that the temple authorities maintain temples very well but often neglect the water structures present in the temple precincts. These water structures are excellent examples of architecture, ornamentation and hydraulic engineering and should be conserved and maintained.

The conservation of such water structures would happen when people realise their value in the present context and their underlying potential of functioning as vibrant public places. A good example of how TWI could be conserved through little adaptive reuse is the Stepwell Café at the Tanwarji Stepwell in Jodhpur. Queen Jay Kanwar- the wife of Maharaj Abhay Singh of Jodhpur, commissioned local masons and artisans to build this stepwell in 1748 A.D (Rathore and Mathur, 2015, p.544). It was constructed using red sandstone and had intricate carvings and motifs along the steps. However, since the beginning of the 20th century, the stepwell existed in a neglected state, filled with construction debris for several years. In 2013, the stepwell captured the attention of the team working on the Urban Regeneration Project of Jodhpur known as the JDH project (Ojha, 2016, p.144).

As part of the overall restoration project, special restoration team worked for several weeks on clearing the industrial waste, construction debris and household trash dumped in the stepwell. The team then treated and reoxygenated its water. A three-floored mansion (see Figure 6.5) formed one of the edges of the stepwell. The Raas group of Hotels took over the mansion and converted into a three-tiered café where people can sit and get a view of the traditional stepwell. While the RAAS group owns the café, the stepwell is still open to the people staying around it who use its water. On the one hand, restoring and maintaining the stepwell has benefitted the common people who have an additional source of water and a public place. On the other hand, it has also benefitted the hotel group by attracting tourists who also turn out to be the potential customers for the café. Thus, the stepwell benefits all the three – common people, tourists and hotel group. Such innovative strategies similar to the one used for restoring the Tanwarji Stepwell in Jodhpur could be used for conserving the TWI in Pune and elsewhere.

However, in doing so, one needs to ensure that TWI continues to remain accessible to the common people.

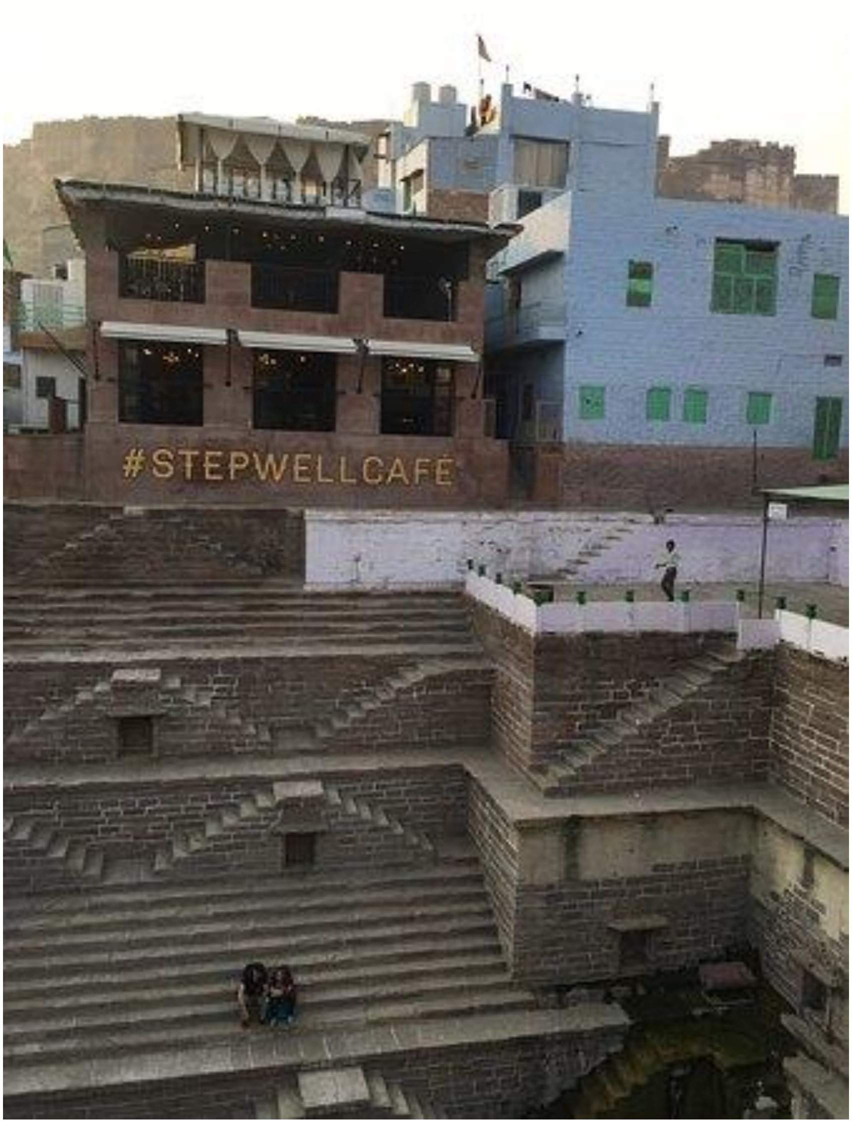


Figure 6.5: Stepwell Café, Jodhpur.
Source:www.tripadvisor.com, 31-07-2019.

Not only does TWI help in creating vibrant public places, but also inspires architects and urban designers in reimagining similar public places in the contemporary socio-cultural context. For instance, the geometry of different kunds has influenced Indian architects such as Charles Correa. In many of his designs, Correa has reinterpreted the kund. While designing the Salt Lake City Centre (2000-2004) in Kolkata, he uses the kund as a focal point in the central plaza where different pedestrian streets meet together. Herein, the kund with a fountain in the middle serves as a pause point and a reference node for people walking through the different shopping complexes.[76] It becomes a vibrant public place for people to spend leisure time, especially in the evenings.

Figure 6.6: A contemporary kund at Salt Lake City Centre, Kolkata.
Source: www.ambujaneotia.com , 23-07-2019.

Figure 6.7: Contemporary interpretation of a kund by Charles Correa at IUCAA, Pune.
Source: www.iucaa.in, 31-07-2019.

Another example of reimagining kunds as public places is the Inter-University Centre for Astronomy and Astrophysics (IUCAA). It is an academic institution in Pune designed by Correa

[76] The information is compiled from www.charlescorrea.net, accessed on 20-07-2019.

during 1988-92 where the kund has a metaphysical significance. Herein, it is a metaphor for the expanding universe. According to Correa, the kund symbolises the union between the traditional conception of the universe by ancient Indians in the form of sacred geometric patterns and the 20th-century notion of expanding universe as understood by scientists such as Einstein, Rutherford, Hoyle, and others (Correa, 2000, p.28). Apart from the kund's symbolism, its pragmatic use as an open-to-sky pleasurable space for scientists, staff and students for meeting each other is equally important.

To summarise, one cannot see TWI from a mere utilitarian perspective. Although its primary function has been capturing, diverting and storing water, the allied features such as celebrating the aesthetics of water and creating vibrant public places are equally important.

The recommendations in this section point out two aspects of water infrastructure management and design. Firstly, water infrastructure management and design cannot judge the value of TWI based merely on the quantity of water it can fetch and compare it with large-scale centralised infrastructure. Both of them operate at different scales based on a different set of principles as already seen in the conclusions. This research does not attempt to underestimate the critical role played by centralised water infrastructure, especially in famine control and spread of irrigation. At the same time, it does not attempt to romanticise TWI. Nonetheless, it points out that one needs to understand both the infrastructures in their historical, political, and cultural context. Considering the costs and benefits of both, one would realize that expanding the existing centralised water infrastructure alone would keep us ill-equipped to face the current and future challenges of climate change, rapid urbanisation, and depleting water resources. Moreover, although these water-related challenges are global (with varying degree), the solutions cannot be global but local, place-specific and sustainable.

Secondly, in future, water infrastructure cannot be isolated and seen from settlement design separately. Both need to go hand in hand. However, taking clues from TWI does not mean that it should reemerge in the city in the form of cisterns and decorative fountains. It means that the future settlements need to function as water catchments themselves and have minimum dependence on external distant water sources. Imagining future settlements in such manner would mean that water infrastructure is no more an add-on entity but an inherent part of settlement design. At the same time, it is necessary to ensure that there is minimum human interference in the natural ecological processes.

6.4. Future Outlook

Generally, as seen in the case of the water infrastructure of Pune, merely identifying it as critical is not enough unless one examines the reasons that make it critical. A historical and cultural examination of water infrastructure in case of this research has made it possible in gaining a deeper insight into the understanding of criticality within a specific cultural context. The case of Pune has shown that in cities of industrialising countries, water infrastructure as such is critical to a limited extent. Incidences of water infrastructure failure occur frequently, and society has developed its means of coping with infrastructure failure. Instead, what becomes critical is the finite availability of water as a natural resource amidst increasing population. Therefore, the current popular deficiency-oriented approach of infrastructure research that concentrates on the notion of an infrastructure failure (Lukitsch et al., 2018, p.15) provides a limited opportunity in future for seeking a solution to the much wider and pressing problem of depletion of natural resources such as water.

The current research on infrastructure failure and its possible impact on human society invariably assume climate change as a mere natural phenomenon from which both infrastructures and humans need to be safeguarded. This research approach neglects the fact that disasters such as floods and droughts are more than mere natural disasters. They are human-created disasters due to lack of planning, foresight and neglect of the ecosystem we live in (Narain, 2017, p.12). Thus, the research outlook in future needs to recognise the fact that both infrastructure and human society would not become resilient to disasters by exercising further control over nature through technological inputs. Instead, it is essential to correct human actions that are the root cause for most of the disasters.

For correcting human actions, it is necessary to bring about a fundamental change in the way we perceive nature. In the case of water infrastructure, it means bringing about a fundamental change in our image of water. We cannot consider water merely as a commodity H_2O essential for the functioning of human activities. Instead, we need to acknowledge the multi-dimensional character of water as a natural resource having life-sustaining, symbolic, religious, and cultural qualities. Only after realising these qualities, we can overcome materialistic thinking about water and design infrastructure that does not seek to control natural water for sustaining human activities.

Another fundamental change that we need to bring about in the research on water infrastructure, in particular, is to proceed beyond the binaries of traditional vs modern, urban vs rural and centralised vs decentralised. As demonstrated in this research, it is necessary to understand that modern science is not the only form of knowledge, and even tacit knowledge plays a critical role in infrastructure design and management of resources. Similarly, in the current context, further research cannot neglect the urban-rural linkages which infrastructures generate. For instance, in the case of water infrastructure, the water supply network may be a part of the urban landscape, but sources of water such as reservoirs are mostly in rural areas. Thus, water infrastructure design and management cannot consider the water requirements of urban areas alone, but also the water requirements in rural areas for domestic and irrigation purposes. Lastly, future research should consider the fact that a complete switch over from centralised to decentralised systems is not practical. Hence, research should focus on how further expansion of centralised systems can be minimised by complementing centralised systems with decentralised systems effectively.

Ultimately, water-related problems are incredibly complex, and there hardly exists any particular solution to fix them instantaneously. This research was a humble attempt of seeking answers to these problems by deriving hints from the traditional knowledge of water infrastructure design and management existing in our ancient culture. The ancient Indian cultural values may not provide direct and quick solutions to our problems, but they teach us to think cosmically, see globally, behave regionally, and act locally but insightfully (Singh, 2017a).

7. Bibliography

Agarwal, Anil; Narain, Sunita (Eds.) (1997): Dying Wisdom. Rise, fall and potential of India's traditional water harvesting systems. 4th ed. Centre for Science and Environment. New Delhi.

Agarwal, Anil; Narain, Sunita; Khurana, Indira (2001): Making Water Everybody's Business. Practice and Policy of Water Harvesting. New Delhi: Centre for Science and Environment.

Agricultural Census (2015): All India Report on Agriculture Census 2010. Department of Agriculture, Co-operation and Farmers Welfare, Government of India. Agriculture Census Division, Department of Agriculture, Co-operation and Farmers Welfare, Government of India. New Delhi. Available online at agcensus.nic.in, checked on 4/11/2017.

Agricultural Census Division (2017): District Tables. Table 5A. Available online at agcensus.dacnet.nic.in/DistSizeClass.aspx, checked on 17/8/2017.

Ahmadi, Hassan; Samani, Aliakbar Nazari; Malekian, Arash (2010): The Qanat: A Living History in Iran. In Graciela Schneier-Madaness (Ed.): Water and Sustainability in Arid Regions. Heidelberg: Springer, pp. 125–138. Available online at www.researchgate.net/publication/226915624_The_Qanat_A_Living_History_in_Iran, checked on 10/3/2019.

Alone, Yashadatta (2002): Forms and patronage in early Buddhist art and architecture. A study of Western Indian Buddhist caves. Ph.D. Jawaharlal Nehru University, New Delhi. Available online at shoodhganaga.inflibnet.ac.in/handle/10603/29313, checked on 3/8/2019.

Apte, Dattatray Vishnu (1923): Maharashtra Itihaas Manjiri. Nivdak Aitihasik Utaare. Pune: Shankar Narhar Joshi. Available online at http://dspace.vpmthane.org:8080/xmlui/handle/123456789/3598, checked on 12/8/2019.

Arcanjo, Marcus (2018): Delaying day zero: Fighting back against water insecurity. The Climate Institute. Washington DC. Available online at http://climate.org/wp-content/uploads/2018/04/Day-Zero-Water-Article.pdf, checked on 7/9/2018.

Arnold, David; Guha, Ramchandra (Eds.) (1995): Nature, Culture, Imperialism. Essays on the Environmental History of South Asia. New Delhi: Oxford University Press.

Arthashastra by Kautilya (1982). Ed by Kangale, R P. Mumbai: Maharashtra Rajya Sahitya Sanskriti Mahamandal.

ASI (2008): Archaeological Survey of India. Lenyadri group of caves. Junnar.

Asia Centre, Seoul National University (2017): ACLA-APELA International Workshop. Illustrating Asia. Seoul, 17-11-2017 to 18-11-2017. Seoul.

Axelby, Richard; Nair, Preetha Savithri (2010): Science and the changing environment in India 1780-1920: a guide to sources in the India Office records. London, UK: British Library Publishing Division.

Baghel, Ravi (2014): River Control in India. Spatial, governmental and subjective dimensions. Switzerland: Springer.

Barah, B C (1996): Traditional Water Harvesting Systems in India. In B C Barah (Ed.): Traditional Water Harvesting Systems. New Delhi, Bangalore, Bombay, Calcutta, Guwahati, Hyderabad, Lucknow, Madras, Pune, Bangkok, London: New Age International Limited, pp. 3–67.

Beinart, William; Hughes, Lotte (2009): Environment and Empire. New York: Oxford University Press.

Berkes, Fikret; Folke, Carl; Gadgil, Madhav (1995): Traditional Ecological Knowledge, Biodiversity, Resilience and Sustainability. In C. A. Perrings, K. G. Mäler, C. S. Holling, B. O. Jansson (Eds.): Biodiversity Conservation. Problems and policies, vol. 4. Dordrecht: Springer, pp. 281–299. Available online at www.ces.iisc.ernet.in/biodiversity/pubs/mg/pdfs/mg138.pdf, checked on 17/2/2017.

Berkes, Fikret; Colding, Johan; Folke Carl (2000): Rediscovery of Traditional Ecological Knowledge as Adaptive Management. In Ecological Applications 10(5), pp. 1251-1262. Available online at links.jstor.org/sici?sici=1051-0761%28200010%2910%3A5%3C1251%3AROTEKA%3E2.0.CO%3B2-8, checked on 20/11/2017.

BES, GOM (1958): Bureau of Economics and Statistics, Government of Maharashtra. Socio-economic review and District statistical abstract of Poona District 1957-58. Bombay. Available online at dspace.gipe.ac.in/xmlui/handle/10973/45662, checked on 20/4/2019.

Bhaduri, Saradindu; Singh, Anushree (2012): Decline of traditional water harvesting systems during British India: Exploring the issues of 'knowledge incompatibility', 'breaking down of the commons' and 'free ridership'. The International Society for Ecological Economics. Available online at www.iseceeco.org/conferences/isee 2012-versao 3/pdf.895.pdf.

Bhan, Ravindra (2008): Birds Oasis. Model Colony Lakaki Lake, Pune. In *Journal of Landscape Architecture* 5 (3), pp. 64–69. Available online at www.scribd.com/document/42313888/La-19-Birds-Oasis, checked on 21/7/2019.

Bhave, Vasudev Krishna (1976): Peshwekaalin Maharashtra. Pune: Varada Publication.

Biggs, J.; von Fumetti, S.; Kelly-Quinn, M. (2017): The importance of small waterbodies for biodiversity and ecosystem services: implications for policy makers. In *Hydrobiologia* 793 (1), pp. 3–39. Available online at https://doi.org/10.1007/s10750-016-3007-0, checked on 22/8/2018.

Bloomberg, Linda Dale; Volpe, Marie (2016): Completing your qualitative dissertation. The roadmap from beginning to end. California: Sage Publications.

Board of Control Records (1840): Measures taken to supply the city of Poona with water during the hot season - a supply of water to be obtained from Sangrun if necessary. British Library, London. [Shelfmark IOR/F/4/1902/81012].

Board of Control Records (1843): Measures undertaken for the general improvement of Poona city. India Office Records, British Library, London. [Shelfmark IOR/F/4/2037/92422].

Boin, Arjen; McConnell, Allan (2007): Preparing for critical infrastructure breakdowns. the limits of crisis management and the need for resilience. In *Journal of Contingencies and Crisis Management* 15, pp. 51–59, checked on 11/6/2017.

Bokhare, Narendra (2005): Rivers in Adivasi Cultures. 305-313. In Chakravarty (K.K.), Badam (G.L.) (Eds.): River Valley Cultures of India. New Delhi: Aryan.

Bose, D. M. (Ed.) (1971): A Concise History of Science in India. With assistance of S. N. Sen, B. V. Subbarayappa. Indian National Science Academy. 1 volume. New Delhi: Indian National Science Academy.

Brihat Samhita, by Varahamihir (1946). In Subramanya V. Sastri, Ramakrishna M. Bhat (Eds.): Varamihir's Brihat Samhita. With an English translation and notes. Mysore: V.B. Soobbiah and Sons.

Brooks, David B. (2005): Beyond greater efficiency. The concept of water soft paths. In *Canadian Water Resources Journal*, pp. 83–92. Available online at www.tandfonline.com/doi/pdf/10.4296/cwrj300183, checked on 24/9/2018.

Bruijne, Mark de; Eeten, Michel van (2007): Systems that should have failed. Critical infrastructure protection in an institutionally fragmented environment. In *Journal of Contingencies and Crisis Management* 15, pp. 18–29. Available online at 10.1111/j.1468-5973.2007.00501.x, checked on 10/10/2017.

Buckley, Robert B. (1880): The irrigation works of India and their financial results. London: Wallen and Co.

Callicott, Baird J.; Ames, Roger T. (1989): Introduction. The Asian Traditions as a Conceptual Resource for Environmental Philosophy. In Baird J. Callicott, Rojer T. Ames (Eds.): Nature. In Asian traditions of thought: State University of New York Press (SUNY Series in Philosophy and Biology), pp. 1–21.

Castree, N. (2001): Introduction. In N. Castree, B. Braun (Eds.): Socializing Nature. Theory, Practice and Policies. NA, USA: Blackwell Publishers, 1-21. Available online at www.researchgate.net/publication/242261258_Socializing_Nature_Theory_Practice_and_Politics, checked on 21/8/2019.

Central Water Commission (2015): Water and Related Statistics. Water Resources Information System Directorate Information Organization. Water Planning and Projects Wing, Central Water Commission. New Delhi.

CGDB (2013): Central Groundwater Development Board. Ground Water Information, Pune District, Maharashtra. Ministry of Water Resources, Government of India. Central Region, Nagpur.

Clark, Josh (2007): Why can't we manufacture water? science.howstuffworks.com/environmental/earth/geophysics/manufacture-water.html, updated on 11/7/2007, checked on 20/8/2019.

Correa, Charles (2000): The Blessings of the Sky. In Kenneth Frampton (Ed.): Charles Correa. London: Thames and Hudson, pp. 17–29.

Dandawate, P. P.; Joshi, P. S. (2005): River Goddesses in Mythology, Literature and Art. In Chakravarty (K.K.), Badam (G.L.) (Eds.): River Valley Cultures of India. New Delhi: Aryan.

Dandawate, P. P.; Joshi, P. S.; Gajul, B. S. (2006): Traditional systems of water management in Maharashtra. In Kalyan Kumar Chakravarty, Gyani Lal Badam, Vijay Paranjpye (Eds.): Traditional Water Management Systems of India. Bhopal, New Delhi: Indira Gandhi Rashtriya Manav Sanghrahalay, Aryan Books International, pp. 3–7.

Dandekar, Parineeta (2015): Muthai river walk. Exploring what was and what could be. South Asia Network on Dams, Rivers and People (SANDRP). Available online at sandrp.in/2015/12/01/muthai-river-walk-exploring-what-was-and-what-can-be/, checked on 18/5/2019.

Darian, Steven (1978): The Ganges in Myth and History. Honolulu: The University Press of Hawaii. Available online at scholarspace.manoa.hawaii.edu › bitstream › #7_Darian.pdf, checked on 24/8/2019.

DCO (2014): Directorate of Census Operations. District Census Handbook Pune. New Delhi (28). Available online at http://censusindia.gov.in/2011census/dchb/2725_PART_B_DCHB_%20PUNE.pdf, checked on 5/4/2019.

Deshmukh, Bhushan (2018): Jalmahal aani Karanji. In Abhijeet Ghorpade (Ed.): Bhavtaal. Udak raakhile yukteene. Pune, pp. 38–42.

Dharashivkar, Mukund (2018): Phad. In Abhijeet Ghorpade (Ed.): Bhavtaal. Udak raakhile yukteene. Pune, pp. 72–75.

Dhavalikar, M. K. (2006): Inamgaon: The Proto-historic Irrigation System. In Kalyan Kumar Chakravarty, Gyani Lal Badam, Vijay Paranjpye (Eds.): Traditional Water Management Systems of India. Bhopal, New Delhi: Indira Gandhi Rashtriya Manav Sanghrahalay, Aryan Books International, pp. 8–14.

Dhavalikar, M. K.; Sankalia, H. D.; Ansari, Z. D. (1988): Excavations at Inamgaon. Vol I, Part i. Deccan College of Post Graduate and Research Institute. Pune.

Dicks, Henry (2014): A phenomenological approach to water in the city: towards a policy of letting water appear. In *Environment and Planning D: Society and Space* 32, pp. 417–432. Available online at http://journals.sagepub.com/doi/pdf/10.1068/d13019p, checked on 9/4/2018.

Diddee, Jayamala; Gupta, Samita (2013): Pune. Queen of Deccan. Pune: INTACH Pune Chapter.

Domenech, Laia (2011): Rethinking water management. From centralized to decentralized water supply and sanitation models. In *Documents d' Analisi Geografica* 57, pp. 293–310. Available online at www.researchgate.net/publication/277107457_Rethinking_water_management_From_centralised_to_decentralised_water_supply_and_sanitation_models, checked on 10/7/2017.

Draft Development Plan of Jejuri. 2nd Revision: Town Planning and Valuation Department.

DSA (2018): District Superintendent of Agriculture. Jalyukta Shivar 2016-2017. District Agriculture Office. Pune.

D'Souza, Rohan (2006): Water in British India. The Making of a 'Colonial Hydrology'. In *History Compass*, pp. 621–628. Available online at www.researchgate.net/publication/227498565_Water_in_British_India_The_Making_of_a_'Colonial_Hydrology', checked on 7/12/2018.

Eck, Diana L. (1981): India's Tirthas: "Crossings" in Sacred Geography (History of World Religions). Available online at http://nrs.harvard.edu/urn-3:HUL.InstRepos:25499831, checked on 10/10/2017.

Egan, M. J. (2007): Anticipating Future Vulnerability. Defining characteristics of increasing critical infrastructure-like systems. In *Journal of Contingencies and Crisis Management* 15 (1), pp. 4–17. Available online at doi.org/10.1111/j.1468-5973.2007.00500.x.

Elwin, Edward (1907): One of the city hauds. British Library London. Photograph: Indian Jottings:From ten years' experience in and around Pune City.

English, Paul Ward (1968): The Origin and Spread of Qanats in the Old World. In *Proceedings of the American Philosophical Society* 112 (3), pp. 170–181. Available online at www.jstor.org/stable/986162, checked on 23/7/2019.

FAO (2016): Food and Agriculture Organization of the United Nations. Water Availability. Aquastat main database. Available online at www.fao.org/3/Y4473E/y4473e08.html, updated on 2016, checked on 20/8/2019.

Farahi, Leila; Motamed, Bahareh; Jumei, Elmira (2016): Persian Gardens. Meanings, symbolism and design. In *IALE* 46, pp. 1–19. Available online at 10.3097/LO.201646, checked on 20/4/2019.

Fekete, Albert; Haidari, Reza (2015): Special aspects of water use in Persian Gardens. In *Agriculture and Environment* 7, pp. 82–88. Available online at 10.1515/ausae-2015-0007, checked on 20/4/2019.

Fergusson, James; Burgess, James (1880): The Cave Temples of India. London: W.H. Allen & Co. Available online at archive.org/32/items/cavetemplesofind00ferguoft/cavetemplesofind00ferguoft.pdf, checked on 6/2/2019.

Fife, R. E. Lieut. Col. (1866): Water Supply of Poona and Kirkee. With Plans and Estimates. Bombay. [Shelfmark BLL01001231753].

Final Development Plan of Junnar (Revised) (2010). Mumbai: Town Planning and Valuation Department. Soft Copy, checked on 28/2/2019.

Gadgil, D. R. (1945): Poona: A socio economic survey. Historical Survey. Gokhale Institute of Politics and Economics. Pune (12). Available online at dspace.gipe.ac.in/xmlui/discover, checked on 21/2/2017.

Galada, Heather C.; Montalo, Franco A; Gurian, Pattrick; Sheller, Mimi; Ayalew, Tibebu B; O'Connor, Stephen (2014): Assessing preferences regarding centralized and decentralized water infrastructure in post-earthquake Leogane, Haiti 5 (5), pp. 1–13. Available online at www.earth-perspectives.com.

Gandhi, M. K. (1928): Satyagraha in South Africa. Edited by Valji Desai. Available online at www.mkgandhi.org/ebks/satyagraha_in_south_africa.pdf, checked on 19/8/2019.

Gandy, Mathew (2004): Rethinking urban metabolism: Water, space and the modern city. In *City* 8 (3), pp. 363–379. Available online at www.tandfonline.com/doi/abs/10.1080/1360481042000313509?journalCode=ccit20, checked on 20/9/2017.

Gandy, Mathew (2008): Landscapes of disaster: water, modernity, and urban fragmentation in Mumbai. In *Environment and Planning* 40, pp. 108–130.

Garge, Tejas (2018): Nahar-e-Ambari. In Abhijeet Ghorpade (Ed.): Bhavtaal. Udak raakhile yukteene. Pune, pp. 43–48.

GBP-XVIII, Part I (1885): Gazetteer of the Bombay Presidency: Volume XVIII Part I: Poona. Bombay

GBP-XVIII, Part II (1885): Gazetteer of the Bombay Presidency: Volume XVIII Part II: Poona. Bombay

GBP-XVIII, Part III (1885): Gazetteer of the Bombay Presidency: Volume XVIII Part III: Poona. Bombay.

GBP-XXIII (1884): Gazetteer of the Bombay Presidency: Volume XXIII, Bijapur. Bombay. Available online at archive.org/details/cu31924070623743/page/n6, checked on 10/3/2019.

GBS-XX (1954): Gazetteer of Bombay State Revised Edition- XX. Poona District. Bombay: Government Central Press. District Series, XX.

Geels, F. W. (2005): Co-evolution of society and technology. The transition in water supply and personal hygiene in the Netherlands (1850-1930). A case study in multi-level perspectives. In *Technology in Society* 27 (3), pp. 363–397. Available online at www.researchgate.net/publication/222300951_Co-evolution_of_technology_and_society_The_transition_in_water_supply_and_personal_hygiene_in_the_Netherlands_1850-1930_-_A_case_study_in_multi-level_perspective, checked on 10/6/2019.

Gehrmann, Simon (2018): ReSource Water. Closing the cycles. Ph.D. Technical University Darmstadt, Darmstadt. Available online at hds.hebis.de/ulbda/Search/Results?lookfor=simon+gehrmann&service=catalog, checked on 25/7/2019.

Ghanekar, P. K. (2006): Traditional water management in the forts of Maharshtra. In Kalyan Kumar Chakravarty, Gyani Lal Badam, Vijay Paranjpye (Eds.): Traditional Water Management Systems of India. Bhopal, New Delhi: Indira Gandhi Rashtriya Manav Sanghrahalay, Aryan Books International, pp. 14–18.

Ghate, Rupali (2011): Development Plans for Pune City. Green Earth Social Development Consulting Pvt. Ltd.

Ghate, Vinaya; Datar, Mandar (2014): Maharashtra. A case study of Sacred Groves in Velhe Taluka of Pune District. In Nanditha Krishna, M. Amirthalingam (Eds.): Sacred Groves of India. Chennai: C.P.R. Environmental Education Centre, pp. 247–252.

Gholikandi, Gagik; Sadrzadeh, Mandana; Jamshidi, Shervin; Ebrahimi, Mortaza (2013): Water resource management in ancient Iran with emphasis on technological approaches. A cultural Hertage. In *Water science and technology*, pp. 582–589. Available online at 10.2166/ws.2013.084.

Gilmartin, David (1994): Scientific Empire and Imperial Science: Colonialism and Irrigation Technology in the Indus Basin. In *The Journal of Asian Studies* 53 (4), pp. 1127–1149. Available online at https://www.cambridge.org/core/services/aop-cambridge-core/content/view/S0021911800044521, checked on 20/12/2017.

Gleick, Peter H. (2000): A look at twenty-first century water resources development. In *Water International* 25 (1), pp. 127–138. Available online at www.tandfonline.com/doi/abs/10.1080/02508060008686804, checked on 4/3/2018.

Gleick, Peter H. (2003): Global Freshwater Resources: Soft Path Solutions for the 21st Century. In *Science* 302, pp. 1524–1528. Available online at http://www.ag.unr.edu/saito/classes/nres400/readings/gleick03a.pdf, checked on 12/4/2017.

Gleick, Peter H.; Wolff, Gary (2002): The soft path for water. Washington DC: Island Press (The World's Water).

Gogate, Shakuntala (1988): Panshetcha Pralay. Anek Purgrasta ni Ek Purtrasta yaanchi apurva satyakatha. Pune: Thosar, G.S.

Gokhale, Balakrishna Govind (1988): Poona in the Eighteenth Century: An Urban History. Delhi: Oxford University Press.

Gokhale, L. R. (1914): Katraj cha Nal. Pune.

Gokhale, Pallavee; Deo, Sushama (2016): Digital reconstruction and visualization of Peshwa period water system of Pune. In *Heritage: Journal of Multidisciplinary Studies in Archeology* 4, pp. 653–669.

Gokhale, Pallavi (2018): Pune: Nahari, Haud aani Ucchwas. In Abhijeet Ghorpade (Ed.): Bhavtaal. Udak raakhile yukteene. Pune, pp. 55–59.

GOM (2012): Government of Maharashtra. Study of water supply systems of Maharashtra Golden Quadrilateral Cities in Delhi-Mumbai Industrial Corridor of the Republic of India. With assistance of Japan International Co-operation Agency.

GOM (2014): Government of Maharashtra. Implementation of Jalyukta Shivar for making Maharashtra drought-free until 2019, checked on 12/5/2014.

Google Earth Pro 7.3.2.5491 (2017): Jejuri Map. 18°16'7.46" N, 74°09'47.61"E. Eye Alt. 1.56km, checked on 18/3/2019.

Google Earth Pro 7.3.2.5491 (2017): Ranje. 18°20'25.30" N, 73°49'21.27"E. Eye Alt. 669m, checked on 18/3/2019.

Google Earth Pro 7.3.2.5491 (2018): Katraj Lake, Pune. 18°26'43.27" N, 73°51'38.06"E. Eye Alt. 1.05km, checked on 18/3/2019.

Google Earth Pro 7.3.2.5491 (2018): Lenyadri Ganesh Caves, Junnar. 19°14'27.11" N, 73°53'06.47"E. Eye Alt. 700m., checked on 30/5/2019.

Google Earth Pro 7.3.2.5491 (2018): Mastani Talav, Vadaki. 18°25'9.50" N, 74°0'0"E. Eye Alt. 844m, checked on 19/3/2019.

Google Earth Pro 7.3.2.5491 (2018): Shivneri Fort, Junnar. 19°11'55.04" N, 73°51'52.24"E. Eye Alt. 2.47km., checked on 30/5/2019.

Google Earth Pro 7.3.2.5491 (2019): Loni Bhapkar. 18°13'41.14" N, 74°23'04.56"E. Eye Alt. 1.42km, checked on 13/2/2019.

Google Earth Pro 7.3.2.5491 (2019): Model Colony Lake, Pune. 18°31'44" N, 73°50'32"E. Eye Alt. 416m, checked on 25/7/2019.

Google Earth Pro 7.3.2.5491: Manchar. 19°0'17.45" N, 73°56'23.34"E. Eye Alt. 802m, checked on 13/2/2019.

Goudie, Andrew (1981): The human impact on the natural environment. Fourth. Oxford, UK: Blackwell Publishers.

Groundwater Surveys and Development Agency (GSDA) (2015): Status of groundwater development in Pune District. Pune.

Guha, Ramachandra (2007): India after Gandhi. The history of the World's largest democracy. London: Macmillan.

Hardiman, David (1995): Small-Dam Systems of the Sahyadris. In David Arnold, Ramchandra Guha (Eds.): Nature, Culture, Imperialism. Essays on the Environmental History of South Asia. New Delhi: Oxford University Press, pp. 185–209.

Hart, Philip Lewis Captain (1858): Report on a Project the Supply of Water to the Poona Cantonment. Bombay. [Shelfmark 001606293].

Heale, Roberta; Forbes, Dorothy (2013): Understanding triangulation in research. In *Evaluation based nursing* 16 (98), p. 98. Available online at 10.1136/eb-2013-101494.

Hegde, Vinayak (2017): Indra on Airavat. Available online at www.flickr.com/photos/vinayakh/36334436123, updated on 8/12/2019, checked on 25/8/2019.

Hegewald, Julia (2002): Water architecture in South Asia. A study of Types, Developments and Meanings. Leiden, Boston, Köln: Brill (Studies in Asian art archaeology, 24).

Hodge, Trevor A. (2000): Qanats. In Örjan Wikander (Ed.): Handbook of Ancient Water Technology. Leiden, Boston, Köln: Brill, pp. 35–38.

Hoekstra, Arjen (1998): Perspectives on Water. An integrated model-based exploration of the future. Utrecht: International Books.

Hoyer, Jacqueline; Dickhaut, Wolfgang; Kronawitter, Lukas; Weber, Bjorn (2011): Water Sensitive Urban Design. Principles and Inspiration for Sustainable Stormwater Management in the City of the Future. Berlin: Jovig Verlag.

Hoyo, Maria; Allen, Dee Dee (2006): Use of triangulation. Methods in Qualitative Research Education. In *Journal of College Science teaching* 35 (4), pp. 42–48. Available online at qualitative%20paper4.pdf, checked on 18/8/2019.

Hui, Rebecca; Wescoat, James L. (2019): Visualising peri-urban and rurban water conditions in Pune district, Maharashtra, India. In *Geoforum* 102, pp. 255–266. Available online at www.sciencedirect.com/science/article/pii/S0016718518300149, checked on 16/8/2019.

ICOLD (2018): International Commission on Large Dams. World register of dams: General synthesis. Available online at http://www.icold-cigb.net/GB/world_register/general_synthesis.asp, checked on 9/11/2018.

ICSU (2002): International Council for Science. Science, Traditional Knowledge and Sustainable Development (ICSU Series on Science for Sustainable Development, 4).

IGI-IV (1909). The Imperial Gazetteer of India: Volume IV: Administrative. Oxford: Clarendon Press.

IIC (1903): Indian Irrigation Commission. Report of the Indian Irrigation Commission 1901-1903: Appendix. Superintendent of Government Printing, India. Calcutta. Available online at ia801602.us.archive.org/30/items/in.ernet.dli.2015.85767/2015.85767.Report-Of-The-Indian-Irrigation-Commission-1901-1903_text.pdf, checked on 18/8/2018.

Illich, Ivan (1985): H2O and the Waters of Forgetfulness. Reflections on the Historicity of Stuff. Dallas, United States of America.

IMD (2016): Indian Meteorological Department. Rainfall Statistics of India. 2015. New Delhi. Available online at http://hydro.imd.gov.in/hydrometweb/(S(ah0kjd55lgvs5siowd4f0jvl))/PRODUCTS/Publications/Rainfall%20Statistics%20of%20India%20-%202015/Rainfall%20Statistics%20of%20India%20-%202015.pdf, checked on 24/10/2017.

IMD (2018): Indian Meteorological Department. Monthly mean maximum and minimum temperature and total rainfall based upon 1901-2000 data. Available online at data.gov.in/catalog/climatology-data-important-cities-5, checked on 11/6/2018.

Inokai, Ravindra Bhatta (2007): A model for rainwater harvesting- The Melukote system. In Sandhya Iyengar (Ed.): Waternama. A collection of traditional practices for water conservation and management in Karnataka. Bangalore: Communication for Development and Learning, pp. 83–88.

Irrigation Works Department (1907): A descriptive account of the working of irrigation works in Deccan and Gujarat: 1905-06. Bombay.

Jacob, Nitya (2013): Jalyatra. A journey through India's water wisdom.

Jadhav, Namdevrao (2008): Shivray: Sab Enterprises.

Jain-Neubauer, Jutta (2016): Introduction. In Jutta Jain-Neubauer (Ed.): Water design. Environment and histories. Mumbai: Marg Foundation, pp. 8–31.

Josephson, Paul (2006): Resources under Regimes. Technology, Environment, and the State. London England: Harvard University Press (Resources Under Regimes. New Histories of Science, Technology, and Medicine).

Joshi, D.; Fawcett, B. (2006): Water, Hindu Mythology and an Unequal Social Order in India. In Terje Tvedt, Terje Oestigaard (Eds.): A history of Water, vol. 3. 3 volumes. London, New York: I.B. Tauris (The World of Water, 3), pp. 119–136.

Joshi, Narayan Vishnu (1868): Pune Shaharache Varnan. Pune: Mansanman Prakashan.

Kaika, Maria; Swyngedouw, Erik (2000): Fetishizing the Modern City: The Phantasmagoria of Urban Technological Networks. In *International Journal of Urban and Regional Research* 24 (1), pp. 120–138. Available online at https://onlinelibrary.wiley.com/doi/epdf/10.1111/1468-2427.00239, checked on 26/4/2018.

Kamble, Sambhaji (2018): Draft Development Plan of Jejuri (2nd Revision): Maharashtra State Town Planning and Valuation Department.

Kane, Pandurang Vaman (1973): History of Dharmashastra. Ancient and Medieval Religious and Civil Law. 5 volumes. Pune: Bhandarkar Oriental Research Institute (4).

Kane, Pandurang Vaman (1974): History of Dharmashastra. Ancient and Medieval Religious and Civil Law. Pune: Bhandarkar Oriental Research Institute (2, Part II).

Kapoor, Subodh (Ed.) (2000): he Hindus. Encyclopedia of Hinduism. 5 volumes. New Delhi: Cosmo Publications (3).

Kapoor, Subodh (Ed.) (2000): he Hindus. Encyclopedia of Hinduism. 5 volumes. New Delhi: Cosmo Publications (5).

Karve, Chintaman Ganesh (Ed.) (1942): Pune Nagar Sanshodhan Vrutta Khand 1-3. Bharat Itihaas Sanshodhak Mandal. 4 volumes. Pune: Chintaman Ganesh Karve, Chitnis Nagar Sanshodhan Samitee (Bharat Itihaas Sanshodhak Mandal Sweeya Granthamala).

Kennedy, W. K.; Rogers, T. A. (1985): Man and Animal- Powered Water Lifting Devices. London: Intermediate Technology Publishers. Available online at http://www.ircwash.org/sites/default/files/230-85HU-1269.pdf, checked on 2/17/2017.

Khaladkar, Varada (2018): Pahilya Kaalvyachee Goshta. In Abhijeet Ghorpade (Ed.): Bhavtaal. Udak raakhile yukteene. Pune, pp. 6–10.

Khare, K. C.; Jadhav, M. S. (2007): Water quality assessment of Katraj Lake, Pune (Maharashtra, India). A case study.

Kharmale, Ramesh (2016a): Historical Barabavdi Junnar. Available online at http://www.nisargramyajunnar.in, checked on 1/3/2019.

Kharmale, Ramesh (2016b): Junnar Water Supply. Electronic to Manas Marathe. Junnar, 3/26/2016. Soft Copy.

Khobrekar, V. G. (2006): Maharashtra Itihaas-Maratha Kaalkhand (Part1). Shivkaal (1630-1707). Mumbai: Maharashtra State Literature and Culture Department. Available online at https://msblc.maharashtra.gov.in/pdf/pdf/Shivkal%20(1630%20te%201707).pdf, checked on 21/2/2017.

Khopkar, G. M. (1951): Poona under the Municipality and under the Corporation. In R. V. Oturkar (Ed.): Poona: Look and Outlook. Poona: The Poona Municipal Corporation, pp. 23–41.

Koparde, Pankaj; Raote, Ninad (2016): Areas of avian richness across an urban-rural setting. A case study selected water-bodies from Pune, Maharashtra, India. In *Indian Birds* 12 (2), pp. 50–55. Available online at www.researchgate.net/publication/309152878_Areas_of_avian_richness_across_an_urban-rural_setting_A_case_study_of_selected_water_bodies_from_Pune_Maharashtra_India, checked on 21/7/2019.

Kosambi, Meera (1980): Bombay and Poona. A Socio-ecological study of two Indian cities 1650-1900. University of Stockholm, Stockholm.

Kothawale, Dilip Rajaram; Deshpande, Nayana Rajendra; Kolli, Rupa Kumar (2016): Long term temperature trends at major, medium, small cities and hill stations in India during the period 1901-2013. In *American Journal of Climate Change* 5, pp. 383–398. Available online at dx.doi.org/10.4236/ajcc.2016.53029, checked on 20/7/2019.

Kramrisch, Stella (1946): The Hindu Temple. Calcutta: University of Calcutta. Available online at archive.org/details/in.ernet.dli.2015.282158., checked on 5/8/2019.

Krishiparashar by Parashar (2003). In Dwarkaprasad Shashtri (Ed.): Krishiparashar. Varanasi: Chaukhamba Krishnadas Academy.

Kulkarni, A. R. (2008): Maharashtra in the Age of Shivaji. 2008th ed. Pune: Diamond Publication.

Kurkute, Abhinav (2018): Kilyanvarchee Taaki. In Abhijeet Ghorpade (Ed.): Bhavtaal. Udak raakhile yukteene. Pune.

LaFreniere, Gilbert F. (1989): World views and environmental ethics. In *The Trumpeter: Journal of Ecosophy* 6 (6), pp. 144–150. Available online at http://trumpeter.athabascau.ca/index.php/trumpet/article/view/758/1130, checked on 15/6/2018.

Law, Bimala Churn (1944): Rivers of India. Historico-Geographical Sketch. Kolkata: Calcutta Geographical Society.

Lawhon, Mary; Nilsson, David; Silver, Jonathan; Ernston, Henrik; Lwasa, Shuaib (2017): Thinking through heterogeneous infrastructure configurations. In Urban Studies, pp. 1–13. Available online at https://www.researchgate.net/publication/317686706_Thinking_through_Heterogeneous_Infrastructure_Configurations.

Liyange, Chamara P.; Yamada, Koichi (2017): Impacts of population growth on the water quality of natural water bodies. In *Sustainability* 9, pp. 1–14. Available online at www.mdpi.com/2071-1050/9/8/1405/pdf, checked on 20/8/2019.

Lord Shiva and Ganga. Available online at www.mygodpictures.com/category/mata-ganga-ji, checked on 5/29/2019.

Lukitsch, Kristof; Müller, Marcel; Stahlhut, Chris (2018): Criticality. In Jens Ivo Engels (Ed.): Key concepts for critical infrastructure research. Darmstadt: Springer VS, pp. 11–21.

Luo, Tiyanyi; Maddocks, Andrew; Iceland, Charles; Ward, Philip; Winsemius, Hessel (2015): World's 15 countries with most people exposed to river floods. World Resources Institute. Available online at www.wri.org/blog/2015/03/world-s-15-countries-most-people-exposed-river-floods, updated on 2015, checked on 11/8/2019.

Majumdar, R. C. (1977): The Maratha Supremacy. Bombay: Bharatiya Vidya Bhavan.

Mani, Vettam (1975): Puranic Encyclopedia. Delhi, Patna, Varanasi: Motilal Banarsidass.

Manteghi, Golnoosh; bin limit, Hasanuddin; Remaz, Dilshan (2015): Water bodies an urban microclimate: A review. In *Modern Applied Science* 9 (6), pp. 1–12. Available online at www.ccsenet.org/journal/index.php/mas/article/view/42398, checked on 30/3/2018.

Marsh, William M.; Kaufman, Martin M. (2013): Physical Geography. Great Systems and Global Environment. New York: Cambridge University Press.

Masse, Bruce; Barber, Elizabeth; Piccardi, Luigi; Barber, Paul (2007): Exploring the nature of myth and its role in science. In L. Piccardi, W. B. Masse (Eds.): Myth and Geology. London: Special Publications, pp. 9–28.

Mate, M. S. (1998): A History of Water Management and Hydraulic Technology in India (1500 B.C. to 1800 A.D.). New Delhi: D.K. Publishers Distributors Pvt. Ltd.

Mate, M. S. (2002): Madhyayugeen Maharashtra. Mumbai: Maharashtra State Literature and Culture Department. Available online at https://msblc.maharashtra.gov.in/pdf/pdf/Madhyayugin%20Maharashtra%20Samajik%20Ani%20Sanskrutik%20Jivan.pdf, checked on 21/2/2017.

Mate, M. S. (2006): Water Management in Ancient and Medieval India. In Kalyan Kumar Chakravarty, Gyani Lal Badam, Vijay Paranjpye (Eds.): Traditional Water Management Systems of India. Bhopal, New Delhi: Indira Gandhi Rashtriya Manav Sanghrahalay, Aryan Books International, pp. 24–33.

Mathison, Sandra (1988): Why Triangulate. In *Educational Researcher*, pp. 13–18. Available online at doi.org/10.3102/0013189X017002013, checked on 18/8/2019.

McGrane, Scott J (2016): Impacts of urbanisation on hydrological and water quality dynamics, and urban water management. A review 61 (13), 2295-1311. Available online at www.tandfonline.com/doi/pdf/10.1080/02626667.2015.1128084?needAccess=true, checked on 20/8/2019.

Minor Irrigation Census (2017): Report of 5th Census of Minor Irrigation Schemes. Maharashtra State - Table 1. Edited by Ministry of Jal Shakti, Department of Water Resources. New Delhi. Available online at http://164.100.229.38/sites/default/files/MI5C/MH/MH5INT7-1.pdf, updated on 2017, checked on 19/8/2019.

Mishra, Anupam (1993): Aaj bhi khare hain talab. 1st ed. New Delhi.

Mishra, Anupam (1995): Rajasthan ki rajat boondein. New Delhi: Gandhi Peace Foundation.

Moledina, M. H. (1953): History of Poona Cantonment 1818-1953. Poona: Poona and Kirkee Cantonments Citizens' Association.

Moon, Vasant (Ed.) (1991): Dr. Babasaheb Ambedkar: Writings and speeches. Education Department, Government of Maharshtra. New Delhi: Dr Ambedkar Foundation.

Morvanchikar, R. S. (2018): Bharatiya Jal Sanskriti: Swarup aani Vyapti. Aurangabad: Vidya Books Publishers.

Mosse, David (2008): Epilogue: The Cultural Politics of Water-A Comparative Perspective. In *Journal of Southern African Studies* 34 (4), pp. 939–948. Available online at https://www.jstor.org/stable/pdf/40283201.pdf?refreqid=excelsior%3A378d32e75940fcaa76f8d5f71caf047a, checked on 25/4/2018.

MUD, GOI (2015): Ministry of Urban Development, Government of India. Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines. Volume 1. New Delhi. Available online at mohua.gov.in/upload/uploadfiles/files/URDPFI%20Guidelines%20Vol%20I(2).pdf, checked on 16/5/2019.

Mundhe, Nitin; Jaybhaye, Ravindra (2017): Chronological development of Pune from 758-2014 AD. In *International Journal of Environment, Ecology, Family and Urban Studies* 7 (7), pp. 33–50.

Mundoli, Seema; Unnikrishnan, Hita; Nagendra, Harini (2016): Nurturing Urban Commons for Sustainable Urbanisation. In *Journal of the India International Centre* 43 (3&4), pp. 258–270.

Murayi, Yaaminey (2016): Ellora -Khuldabad-Daulatabad. Water and sacred places. In Jutta Jain-Neubauer (Ed.): Water design. Environment and histories. Mumbai: Marg Foundation, pp. 128–141.

Naik, Sonali; Mishra, Sheila (1997): The Chalcolithic Phase in the Bhima Basin, Maharashtra. A review. In *Man and Environment* XXII (1), pp. 45–58.

Narain, Sunita (2006): Community-led Alternatives to Water Management: India Case Study. In *Human Development Report*.

Narain, Sunita (2017): Foreword. In Richard Mahapatra, Snigdha Das (Eds.): Drought but why? New Delhi: Centre for Science and Environment, pp. 12–20.

Nawre, Alpa (2019): Between community and culture. The criticality of landscape infrastructure reuse in India. In *Journal of Landscape Architecture* 13 (3), pp. 54–63. Available online at doi.org/10.1080/18626033.2018.1589141, checked on 16/7/2019.

Naz, Farhat; Subramanian, Saravanan V. (2010): Water Management across Space and Time in India. Bonn (61). Available online at http://nbn-resolving.de/urn:nbn:de:101:1-201009212409.

Nehru Memorial Museum and Library (2015): Nehru 125 Years. Available online at http://nehrumemorial.nic.in/en/digital-archives/category/69-nehru-and-dams.html.

NRLD (2017): National Register of Large Dams. Central Water Commission (CWC), Union Ministry of Water Resources. Available online at www.cwc.nic.in/main/downloads/NRLD-04012017.pdf, checked on 4/11/2017.

Oestigaard, Terje (2009): Water, culture and identity. Comparing past and present traditions in the Nile Basin Region. Bergen: BRIC Press. Available online at www.researchgate.net/publication/287596126_Water_Culture_and_Identity_Comparing_Past_and_Present_Traditions_in_the_Nile_Basin_Region, checked on 20/5/2019.

Ojha, Abhilasha (2016): Blueprint. In *Architectural Digest* July-August, pp. 144–145. Available online at http://www.stepwellcafe.com/pdf/JDH%20in%20AD%20Aug%202016.pdf.

Ostrom, Elinor (1992): Crafting Institutions for Self-Governing Irrigation Systems. San Francisco, California: International Center for Self Governance. Available online at http://pdf.usaid.gov/pdf_docs/PNABL484.pdf.

Oturkar, R. V. (1951): Poona: Historical. In R. V. Oturkar (Ed.): Poona: Look and Outlook. Poona: The Poona Municipal Corporation, pp. 8–18.

Pahl-Wostl, Claudia; Isendahl, Nicola; Möllenkamp, Sabine; Brugnach, Marcela; Jeffrey, Paul; Medema, Wietske; Tessa de Vries, Tony (2006): Paradigms in water management. NeWater. Available online at www.newater.info.

Pahl-Wostl, Claudia; Tabara, David; Bauwen, Rene; Craps, Marc; Dewulf, Art; Mostert, Erik et al. (2008): The importance of social learning and culture for sustainable water management. In *Ecological Economics* 64, pp. 484–495, checked on 19/5/2019.

Pahl-Wostl, Claudia; Vörösmarty, Charles; Rockström, Johan; Alcamo, Joseph (2013): Towards a sustainable water future. shaping the next decade of global water research. In *Current Option in Environmental Sustainability* 5, pp. 708–714. Available online at www.researchgate.net/publication/259167940_Towards_a_sustainable_water_future_Shaping_the_next_decade_of_global_water_research, checked on 9/6/2018.

Pandit, Suraj (2018): Lenyateel Taaki. In Abhijeet Ghorpade (Ed.): Bhavtaal. Udak raakhile yukteene. Pune, pp. 89–93.

Paranjape, Amit (2011): 12 July 1961 - Panshet. A day that changed Pune. Pune. Available online at aparanjape.wordpress.com/2011/07/10/12-july-1961-panshet-a-day-that-changed-pune/, updated on 7/10/2011, checked on 13/7/2018.

Paranjpye, Vijay; Paranjpye, Anjali (2005): River valley cultures at cross-roads: On the threshold of the second millennium. In Chakravarty (K.K.), Badam (G.L.) (Eds.): River Valley Cultures of India. New Delhi: Aryan, pp. 333–342.

Parasnis, D. B. (1921): Poona in Bygone Days. Bombay: The Times Press.

Pathak, Arunchandra (2018): Baarav. In Abhijeet Ghorpade (Ed.): Bhavtaal. Udak raakhile yukteene. Pune, pp. 76–81.

Pathak, Arunchandra Shankarrao (2017): Mahaarashtrateel barav sthapatya aani paaramparik jalvyavasthapan. Pune: Aparant.

Patil, R. K. (2006): Phad System of Western Maharshtra. A traditional method of water harvesting and management by farmers. In Kalyan Kumar Chakravarty, Gyani Lal Badam, Vijay Paranjpye (Eds.): Traditional Water Management Systems of India. Bhopal, New Delhi: Indira Gandhi Rashtriya Manav Sanghrahalay, Aryan Books International; Indira Gandhi Rashtriya Manav Sangrahalaya; Aryan Books International, pp. 117–128.

Pawar, S. G.; Pawar, S. S.; Kamble, V. M.; Kamble, S. Y.; Singh, E. A. (2016): Quantitative evaluation of plant diversity from newly reported sacred groves (devrais) in Pune District (Maharashtra). In *Asian Journal of Multidisciplinary Studies* 4 (10), pp. 58–66. Available online at www.researchgate.net/publication/280228877_Quantitative_assessment_of_plant_diversity_bioresource_values_and_conservation_of_tropical_forests_of_Southern_Eastern_Ghats_India.pdf, checked on 29/4/2019.

Perysinaki, Aliki-Myrto (2010): How do waterscape projects combine landscape design and natural processes to create dialogues that engage both culture and nature? The case of the Boston park system and the solar city. With assistance of Daniel Thevenot. World Wide Workshop for Young Environmental Scientists. France. Available online at hal.archives-ouvertes.fr/hal-00521475, checked on 12/9/2018.

Peshwe Daftar (3/30/1740).

Photograph: Parvati Talav. London: British Library [Shelfmark 866/3 (35)]

Piccardi, L.; Masse, W. B. (Eds.) (2007): Myth and Geology. The Geological Society of London. London: Special Publications.

Pierotti, Raymond; Wildcat, Daniel (2000): Traditional ecological knowledge. The third alternative. In *Ecological Applications* 10 (5), pp. 1333–1340. Available online at www.fws.gov/nativeamerican/pdf/tek-pierrotti-wildcat-2000.pdf, checked on 16/8/2019.

Planning Commission (1951): 1st Five Year Plan. New Delhi. Available online at http://planningcommission.nic.in/plans/planrel/fiveyr/welcome.html, checked on 14/10/2018.

Planning Commission (2013): Twelfth Five Year Plan (2012-2017). Faster, more inclusive and sustainable growth. Volume I. New Delhi. Available online at http://planningcommission.gov.in/plans/planrel/12thplan/pdf/12fyp_vol1.pdf, checked on 4/11/2017.

PMC (1952): Poona Municipal Corporation. An outline of a master plan for Greater Poona. Poona.

PMC (2014): Pune Municipal Corporation. Water supply system for Pune city. Detailed Project Report. Studio Galli Ingegneria. Pune.

PMC (2018): Pune Municipal Corporation. Lakes in PMC Area. Available online at opendata.punecorporation.org/Citizen/CitizenDatasets/Index?categoryId=28, checked on 16/10/2018.

PMC (2018): Pune Municipal Corporation. Monthly analysis of water supply and distribution. Pune. Available online at opendata.punecorporation.org/Citizen/CitizenDatasets/Index?categoryId=28, checked on 16/10/2018.

PMRDA (2016): Pune Metropolitan Region Development Authority. PMRDA Plan. Available online at www.pmrda.gov.in/images/PMRDA%20Region1.jpg, checked online on 10/10/2018.

PMRPB (1970): Poona Metropolitan Regional Planning Board. Regional Plan for Poona Metropolitan Region: 1970-1991. Poona.

Poona City Survey IOR/X/9864/22 (1876).

Poona City Survey IOR/X/9864/24 (1876).

Poona City Survey IOR/X/9864/29 (1877).

Poona City Survey IOR/X/9864/30 (1876).

Poona City Survey IOR/X/9864/34 (1876).

PWD (1942): Public Works Department. Irrigation administrative report, province of Bombay. Part I. For the year 1941-42. Bombay.

Rao, M. G. (1979): Nagarjuna Sagar. The Epic of a Great Temple of Humanity : World’s Largest Masonry Dam: Bharatiya Vidya Bhavan.

Rao, M. Gopal (1979): Nagarjuna Sagar: The epic of a great temple of humanity - World's largest masonry dam.: Bharatiya Vidya Bhavan.

Rathore, Shiv Singh; Mathur, Suresh Chandra (2015): Journey of the Jodhpur City since its foundation through water impounding structures. In K. L. Shrivastava, P. K. Shrivastava (Eds.): Frontiers of Earth Science. Jodhpur: Scientific Publishers, pp. 527–550.

Rodrigues, Livi (1998): Rural Political Protest in Western India. Delhi, New York: Oxford University Press.

Rudolph-Cleff, Annette and Shankar, Pratyush: Making the invisible, visible. In: Carrecedo Gracia-Villalba, Oscar (Ed.): Designing Resilience in Asia. Planning the unpredictable, designing with uncertainty. Volume 1, Altar Publication. ISBN:978-1-948-76525-1 (Forthcoming).

Sagare, Minal (2018): Place making and architecture at Sangam: A study of temple precincts at Sangam Mahuli, Satara. Pune: Masa Fellowship Programme 2013.

Sahni, Binda Preet (2013): A legal analysis of the British East India Company. In *Acta Juridica Hungarica* 54 (2), pp. 317–330. Available online at real.mtak.hu/43250/1/ajur.54.2013.4.2.pdf, checked on 2/5/2019.

Sakal Reporter (2019): Sansarache Paani paani. In *Sakal*, 9/28/2019, p. 1. Available online at www.esakl.com, checked on 9/28/2019.

Sankalia, H. D.; Ansari, Z. D.; Dhavalikar, M. K. (1971): Inamgaon: A Chalcolithic Settlement in Western India. In *Asian Perspectives* 14, pp. 139–145. Available online at https://scholarspace.manoa.hawaii.edu/bitstream/10125/19138/1/AP-v14n1-139-146.pdf, checked on 20/2/2017.

Sankalia, H. D.; Ansari, Z. D.; Dhavalikar, M. K. (1975): An Early Farmers' Village in Central India. In *Expedition, University of Pennsylvania Museum of Archeology and Anthropology* 17 (2), pp. 2–11. Available online at https://www.penn.museum/documents/publications/expedition/PDFs/17-2/Sankalia.pdf, checked on 21/2/2017.

Sapkota, Mukta; Arora, Meenakshi; Malano, Hector; Moglia, Magnus; Sharma, Ashok; George, Biju; Pamminger, Francis (2015): An Overview of Hybrid Water Supply Systems in the Context of Urban Water Management: Challenges and Opportunities (7).

Sastri, Subramanya V.; Bhat, Ramakrishna M. (Eds.) (1946): Varamihir's Brihat Samhita. With an English translation and notes. Mysore: V.B. Soobbiah and Sons.

Sauer, Carl O. (1925): The Morphology of Landscape. Berkley: University of California Press. Available online at http://geog.uoregon.edu/amarcus/geog620/readings/sauer_1925_morphology_of_landscape.pdf.

Schenk, Gerrit (2015): 'Learning from History'? Chances, problems and limits of learning from historical natural disasters. In Fred Krüger, Greg Bankoff, Terry Cannon, Benedikt Orlowski, Lisa E. Schipper (Eds.): Cultures and Disasters. Understanding cultural framings in disaster risk reduction. London, New York: Routledge (Routledge Studies in Hazards, Disaster Risk Reduction and Climate Adaptation), pp. 72–87.

Schramm, Engelbert; Felmeden, Jörg (2012): Towards more resilient water infrastructures. In K. Otto-Zimmermann (Ed.): Resilient Cities 2. Sustainability. Dordrecht: Springer, pp. 177–186.

Schug, Gwen Robins (2011): Bioarchaeology and climate change. A view from South Asian Prehistory. Gainesville: University Press of Florida. [Shelfmark BLL01015795451].

Sengupta, M; Dalwani, R (Eds.) (2007): Taal 2007. The 12th World Lake Conference. The 12th World Lake Conference. Jaipur, 28-10-2007 to 02-11-2007. Ministry of Environment and Forests, India.

Sengupta, Nirmal (1980): The indigenous irrigation organisation in South Bihar. In *The Indian Economic and Social History Review* XVII (2), pp. 157–189.

Sengupta, Nirmal (1993): User-Friendly Irrigation Systems. New Delhi, California, London: Sage Publications.

Sengupta, Nirmal (2007): Neglected Sources of Irrigation. In Nirmal Sengupta (Ed.): Economic Studies of Indigenous and Traditional Knowledge. New Delhi: Academic Foundation, pp. 121–146.

Setegn, S.; Donoso, M. (Eds.) (2015): Sustainability of integrated water management. Cham: Springer.

Shankar, Pratyush (2014): Himalayan Cities. Settlement Patterns, Public Places and Architecture. New Delhi: Niyogi Books.

Shiva, Vandana (1991): The Violence of the Green Revolution. Third World Agriculture, Ecology and Politics. London, New Jersey, Penang: Zed Books Ltd, Third World Network.

Shiva, Vandana (2002): Water Wars. Privatization, Pollution, and Profit. Cambridge, MA: South End Press.

Shiva, Vandana (2008): From water crisis to water culture. In *Cultural Studies* 22 (3-4), pp. 498–509. Available online at www.tandfonline.com/doi/abs/10.1080/09502380802012591?journalCode=rcus20, checked on 30/7/2019.

Singh, Nirmal (1997): A note on the concept of Satyagraha. In *Indian Philosophical Quarterly* XXIV, pp. 521–526. Available online at http://www.unipune.ac.in/snc/cssh/ipq/english/IPQ/21-25%20volumes/24%2004/PDF/24-4-6.pdf, checked on 19/8/2019.

Singh, Rana P. (1994): Water symbolism and sacred landscape in Hinduism: a study of Benares (Varanasi). In *Erdkunde* 48 (3), pp. 210–227.

Singh, Rana P.B. (2013): Indian cultural landscape vis-a-vis ecological cosmology: A vision for the 21st century. In *Annals*, pp. 36–62. Available online at www.researchgate.net/publication/320003080_Urban_Cultural_Landscapes_and_Sacredscapes_the_Indian_Vision, checked on 23/4/2019.

Singh, Rana P.B. (2017a): Cultural Landscape as National Identity. Illustrating Asia-ACLA Vision. In: ACLA-APELA International Workshop. Illustrating Asia. Seoul, 17-11-2017 to 18-11-2017. Asia Centre, Seoul National University. Seoul, pp. 1–20. Available online at www.researchgate.net/publication/321004054_51217_Singh_Rana_PB_2017_17_Nov_Cultural_Landscape_as_National_Identity_Illustrating_Asia_-_ACLA_Vision_A_Keynote_address_in_the_ACLA-APELA_International_Workshop_Cultural_Landscape_as_National_Identity., checked on 30/7/2019.

Singh, Rana P.B. (2017b): Urban Cultural Landscapes and Sacredscapes. The Indian Vision. In : Urban Cultural Landscape and Urban Regeneration. With assistance of Laboratory of Urban and Landscape Design. Urban Cultural Landscape and Urban Regeneration. Vladivostok, Russia, 22-07-2017 to 24-07-2017, pp. 1–17. Available online at www.researchgate.net/publication/320003080_Urban_Cultural_Landscapes_and_Sacredscapes_the_Indian_Vision, checked on 27/7/2019.

Soini, Katriina; Dessein, Joost (2016): Culture-Sustainability Relation. Towards a conceptual framework. In *Sustainability* 8, pp. 1–12. Available online at http://scholar.google.de/scholar_url?url=https://www.mdpi.com/2071-1050/8/2/167/pdf&hl=en&sa=X&scisig=AAGBfm0g-_oS9OBu8vZZRwSxyeG7wx-t2g&nossl=1&oi=scholarr, checked on 19/8/2019.

Sonawane, Ashok (2018): Ahilyadevi Holkar. In Abhijeet Ghorpade (Ed.): Bhavtaal. Udak raakhile yukteene. Pune, p. 125.

Sowani, Avinash (2011): Maratha Town and City Planning. With reference to The Systems of Village Development during 17th and 18th centuries. Doctoral, Tilak Maharashtra Vidyapeeth. Available online at shodhganga.inflibnet.ac.in:8080/jspui/handle/10603/2476, checked on 27/7/2016.

Sowani, Avinash (2017): Haravalele Pune. 2nd ed. Pune: Unmesh Prakashan.

Srinivasan, T. M. (1970): Water-Lifting Devices in Ancient India: Their origin and mechanisms. In *Indian Journal of History of Science* 5 (5), pp. 379–389.

Srinivasan, T. M. (1975): Measurement of rainfall in ancient India, pp. 148–157. Available online at www.insa.nic.in/writereaddata/UpLoadedFiles/IJHS/Vol11_2_6_TMSrinivasan.pdf, checked on 25/4/2019.

Stadler, Laurent; Daro, Carlotta (2017): Eight points on infrastructure and architecture. In Ilka Ruby, Andreas Ruby (Eds.): Infrastructure space. Berlin, Zurich: Ruby Press, Lafarge Holcim Foundation for Sustainable Construction, pp. 26–29.

Stokman, Antje (2008): Water purificative landscapes. Constructed ecologies and contemporary urbanism. In Wybe Kuitert (Ed.): Transforming with water. 45th World Congress of the International Federation of Landscape Architects. Blauwdruk. Wageningen: Techne Press, pp. 51–61. Available online at www.researchgate.net/publication/228620266_Water_purificative_landscapes-constructed_ecologies_and_contemporary_urbanism.

Strang, Veronica (2009): *Gardening the world: Agency, identity, and the ownership of water.* Oxford/New York: Berghahn Publishers.

Strang, Veronica (2011): Representing water. Visual anthropology and divergent trajectories in human environment relations. In *Auario Anthropologio*, pp. 213–242. Available online at 10.40000/aa.1175, checked on 29/1/2019.

Talwalkar, Gopinath Ganesh (1936): Pune (June va Nave). Mumbai: Damodar Savalaram aani Mandali.

The World Bank (2010): Deep wells and prudence. Towards pragmatic action for addressing groundwater overexploitation in India. Washington DC. Available online at http://documents.worldbank.org/curated/en/272661468267911138/pdf/516760ESW0P0951round0Water129101110.pdf, checked on 10/5/2019.

Tiseo, Ian (2019): Number of rainy days in U.K. Available online at www.statista.com/statistics/584922/number-of-rainy-days in U.K., updated on 8/9/2019, checked on 10/8/2019.

Tvedt, Terje (2010): Why England and not China and India? Water systems and the history of the Industrial Revolution. In *Journal of Global History* 5, pp. 29–50.

Tvedt, Terje; Oestigaard, Terje (2006): Introduction. In Terje Tvedt, Terje Oestigaard (Eds.): A history of Water. 3 volumes. London, New York: I.B. Tauris (The World of Water, 3), pp. ix–xxii.

UNESCO (1995): Involving Culture. A fieldworker's guide to culturally sensitive development. With assistance of Canadian International Development Agency. Edited by Helgi Eyford, Glen Eyford. Paris.

Vairavamoorthy, K.; Eckart, J.; Tsegaye, S.; Ghebremichael, K.; Khatri, K. (2015): A paradigm shift in water management. An imperative to achieve sustainability. In S. Setegn, M. Donoso (Eds.): Sustainability of integrated water management. Cham: Springer, pp. 51–64. Available online at link.springer.com/chapter/10.1007/978-3-319-12194-9_4.

Valdesuso, Carlos (2011): Where is the wisdom we have lost in knowledge? Adizes Institute. Brazil. Available online at www.adizes.com/articles/cval-where-wisdom.pdf, checked on 29/7/2019.

Vijaydhwaja (2016): Dashavtar Hari Gatha. Edited by N Balasubramanian. Available online at sanskritdocuments.org/doc_vishnudashAvatArahariGatha.pdf, checked on 25/8/2019.

Vleuten, Erik; Högselius, Per; Hommels, Anique; Kaijser, Arne (2013): Europe's critical infrastructure and its vulnerabilities. Promises, problems, paradoxes. In Per Högselius, Anique Hommels, Anique Kaijser, Erik van der Vleuten (Eds.): The making of Europe's critical infrastructure. Common Connections and Shared Vulnerabilities. Hampshire: Palgrave Macmillan, pp. 3–22.

Wamuchiru, Elizabeth (2017): Rethinking the networked city. The (co-) production of heterogenous water supply infrastructure in Nairobi, Kenya. Ph.D Technical University, Darmstadt., Darmstadt. Available online at tuprints.ulb.tu-darmstadt.de/id/eprint/6957, checked on 2/2/2019.

Whitcombe, Elizabeth (1983): Irrigation. In Dharma Kumar (Ed.): The Cambridge Economic History of India. 1757-1970, vol. 2. With assistance of Meghnad Desai. 2 volumes. Cambridge: Cambridge University Press (2), pp. 677–737.

Whitcombe, Elizabeth (1995): The Environmental Costs of Irrigation in British India: Waterlogging, Salinity, Malaria. In David Arnold, Ramchandra Guha (Eds.): Nature, Culture, Imperialism. Essays on the Environmental History of South Asia. New Delhi: Oxford University Press, pp. 237–259.

Wong, Tony; Brown, Rebekah (Eds.) (2008): Transitioning to Water Sensitive Cities. Ensuring Resilience through a new Hydro-Social Contract. 11th International Conference on Urban Drainage. Edinburgh. Edinburgh. Available online at https://web.sbe.hw.ac.uk/staffprofiles/bdgsa/11th_International_Conference_on_Urban_Drainage_CD/ICUD08/pdfs/638.pdf, checked on 21/2/2017.

Worster, Donald (1985): Rivers of Empire. Water, Aridity and the growth of the American West. New York.

www.ambujaneotia.com/business_vertical/city-centre-salt-lake/ (2019): City Centre Salt Lake, 23/7/2019.

www.charlescorrea.net (2019): Salt Lake City Centre. 2000-2004, 20/7/2019.

www.iucaa.in/~library/photogal/building/BU6.jpg (2019): Central kund at the centre of IUCAA complex, 31/7/2019.

www.mygodpictures.com/wp-content/uploads/2015/07/Lord-Shiva-And-Goddess-Ganga.jpg (2019): Lord Shiva and Goddess Ganga, 3/6/2019

www.punerealestate.com/modelcolony_pune/pathways_modelcolony.html (2019): Lakaki Lake, 31/7/2019.

www.ravindrabhan.com/model-colony-lake?lightbox=dataItem-iv2caddi1 (2019): Model Colony Lake, 23/7/2019.

www.tripadvisor.com/LocationPhotoDirectLink-g297668-d10224839-i236666929-The_Step_Well_House_Cafe-Jodhpur_Jodhpur_District_Rajasthan.html (2019): The Step Well House Cafe, 31/7/2019.

8. Appendices

8.1. Appendix 1

Expert Semi-Structured Interview:
Mr Gaikwad: Deputy Engineer, Parvati Water Treatment Works, Pune
Date of Interview: 14-02-2018

Interviewer: What is the daily water requirement of Pune?

Interviewee: Daily, we supply 1400 mld of water.

Interviewer: Which areas receive water from here?

Interviewee: Many areas have been combined. Earlier 60% of the city received water from here.

Interviewer: How many water treatment plants are there in PMC?

Interviewee: There are five plants.

Interviewer: Are the proposed included in these?

Interviewee: There are no proposed WTPs, only proposal is for piping, lining, network.

Interviewer: How does the water come from Khadakwasla?

Interviewee: The are two pipe systems: pipeline with diameter 3000mm and another with 1000 mm.

Interviewer: How much water is supplied daily?

Interviewee: 1400 mld.

Interviewer: What about the Bhama Askhed project?

Interviewee: The project is under process.

Interviewer: How many dams are there in total?

Interviewee: There are four dams one on top of another. PMC has entered into an agreement with Irrigation Department. There is a recording device near the main intake, which measures the quantity and then calculates the final value.

Interviewer: Does Pune receive water from Panshet and Khadakwasla?

Interviewee: They are above. Khadakwasla is the main point. From Khadakwasla water is stored in the storage tanks.

Interviewer: What about sewage treatment?

Interviewee: A 1kmv capacity project is planned. Japan is funding it. 50% of funds are to be raised by us and 50% from Japan.

Interviewer: Where are the storage reservoirs located?

Interviewee: Those are in different zones. They are at high level, mid-level and low-level.

Interviewer: If water is to be pumped to Deccan, how it is done?

Interviewee: From here, it goes to the reservoir and from there to the concerned area network.

Interviewer: Does every area have a reservoir?

Interviewee: No. Every area does not. The new tender has proposed some of ½ acre, some of 1 ½ acre.

Interviewer: Are there maps showing these?

Interviewee: They are located at Savarkar Bhavan. Our duty is just to pump water from here. The distribution comes under the Swargate Department. There are three zones in total. First is SNDT zone, which includes Kothrud, Dattawadi, Paud Road, Karvenagar. Second id Parvati Zone containing Bibwewadi, Dhankawdi and third is Lashkar Zone that had Koregaon Park, Hadapsar, Kharadi.

Interviewer: How is the water filtered here?

Interviewee: Water enters the intake chamber. There is a clarifier. There are eight mixers where we rechlorinate water using alum, KE. Then it goes to flash mixer. From there to settling tank. The silt settles down. It is removed from the chambers beneath. Then from filter beds it goes to the reservoirs. Here, it is again force chlorinated.

Interviewer: Considering the increasing water demand, how much water do consider is required per person? What is your calculation based on?

Interviewee: 135 litres is required, but as the population is more than 50,00,000, we consider 150 litres. The lines have become old. The leakage is around 30%.

Interviewer: How old are all these pipes?

Interviewee: As area expanded, these pipelines were extended. Most of them belong to 1970s.

Interviewer: Is water from Katraj aqueduct used?

Interviewee: Not for drinking. For other uses.

Interviewer: I saw tankers outside. How do they operate?

Interviewee: It is like this that PMC has to provide water to the surrounding villages that are at a distance of 5km from its jurisdiction.

Interviewer: How many tankers operate daily?

Interviewee: Around 100-150 daily. In summer more.

Interviewer: What is the capacity of a single tanker?

Interviewee: One tanker is of 10000 litres.

Interviewer: I have seen some tankers being filled at Pirangut. Do they get filled there?

Interviewee: They are there sometimes. But they fill otherwise on pumping stations at Patwardhan Baug, Karvenagar, Lashkar, Vadgaon. People use water for construction work.

Interviewer: I have read that as the municipal network expands to villages, people there give up their traditional systems. Is it? Can you link municipal network to these traditional systems?

Interviewee: It is like this. We take their systems into our possession. We have taken few wells at Vadgaon in our possession. We are trying to connect these wells to the network so that we can calculate how much raw water can be obtained. Where there are no wells, we provide our network. We have a pumping station and WTP at Sitainagar near Sinhgad College.

Interviewer: Are there separate lines for Parvati and Hadapsar?

Interviewee: We have pumping station at Padmavati. From there we provide water to Lashkar. We are building another project there.

Interviewer: Are the Mutha Left and Right Bank Canals built by the British still existing?

Interviewee: This is right bank canal. The left bank canal was there at Warje that was closed down. Right Bank Canal is taken up to Daund.

8.2. Appendix 2

Expert Semi-Structured Interview:
Mr Vinit Phadnis, Geologist, Urdhwam.
Date of Interview: 25-02-2018

Interviewer: As a technical expert, what do you think are the reasons for current water scarcity?

Interviewee: As an organisation, our aim is more on groundwater conservation. The reason is that 80% India is dependent on groundwater and all our policies and all our regulations are more for surface water. There is hardly anything for groundwater and when you are dependent 80% on groundwater for domestic and agricultural, industrial needs then it is a global phenomenon that groundwater sources are depleting day by day. There will be time in the next 10-20 years when there is severe condition as far as groundwater is concerned and we have monsoon. Again, if you see the historic data, barring the rivers which are originating in the Himalayas, they may be perennial. But the rivers which are peninsular part of India are becoming more and more drier. If we take Kaveri, there is a problem. Krishna has some perennial flow. Godavari has little but still the quantity is dropping day by day. The main reason for this is groundwater depletion. You have rainfall, you have some amount which is running off but there is much part which is infiltrated inside so eventually aquifers feedback the system, and then they keep them alive. Now our rate of abstraction is so high as compared to the natural processes of infiltration that as the aquifers turn dry, their feeding capacity will reduce. So, it is again takinf=g a bigger troll in terms of surface water resources as well because you have somewhere built dams on those rivers. So the continuous flow has diminished. Their capacities have also reduced. There other issues of desiltation and others involved too.

Interviewer: Is it true that the Deccan trap in Pune region is difficult for infiltration?

Interviewee: Infiltration is difficult because the rock is not conducive to radially absorb, so we have to always consider to increase artificial recharge. We have to find this. If we think of the Pune Jurisdiction in 1950, 1980, 2000 and 2018, there is almost 200% increase in the area. When Khdakwasla was planned it was planned for X inhabitants within a particular boundary. Therefore, the residents beyond the boundary, for instance, Baner, Aundh, Narhe Ambegaon, Kharadi, Vimananagar are not being fed by PMC. They are mainly dependent on groundwater. The piped water system is limited to city centre. The groundwater data for last 10-15 years shows that groundwater extraction is higher in the fringe areas and it is quite OK in the central portion of Pune. So it’s a reverse situation. Also, there is water mining going on in the fringe areas. So there is imbalance.

Interviewer: What is your opinion about the Jalyukta Shivar mission of the Government? I find that there are two opinions: One who think it is a success and others who think it is unsuccessful.

Interviewee: As a geologist, before Jlyukta Shivar, there was a similar project undertaken in Nandurbar area. There was a person who had developed it considering the geology of that area. Now it is if you have to stitch a shirt, then my size and your size is different. So similarly one model cannot be used as it is somewhere else. The advantage of deepening the existing structures was that the storage capacity increased. But whether the recharge increased or not needs to be investigated.

Interviewer: How is the quality of groundwater in Pune?

Interviewee: There are certain patches in Maharashtra where there are groundwater issues in certain areas and there is high concentration of fluorides, arsenic in some places. But these have not been reported in Pune. There have been no issues reported so far. There are some issues of pathogens and E.coli.

Interviewer: What if there is mixing of drainage?

Interviewee: It can be cured by filtration.

Interviewer: In Pune do we have issues like contamination of groundwater due to fertilisers?

Interviewee: No, because the condition here is different. There you have unconcentrated material as aquifer material, sand and gravel. Here we have hard rock so it takes long for groundwater to penetrate. Still we must ensure that we dig shallow dug wells but not deeper tubewells.

8.3. Appendix 3

Expert Semi-Structured Interview:
Mr P.D. Shinde, Assistant Engineer, Irrigation Department
Date of Interview: 16-03-2018.

Interviewer: How much water does PMC use from Khadakwasla Reservoir?

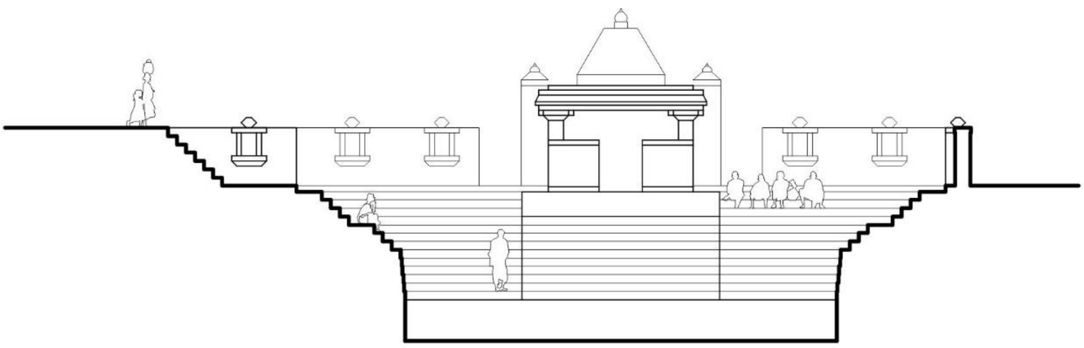
Interviewee: As per the agreement, it should be 11.5 TMC. But in actual it uses 15 TMC. Besides MSEB has installed 8hp pumps on Varasgaon and Panshet Dams.

Interviewer: Does it supply water to other places besides Pune?

Interviewee: It supplies water to four talukas: Haveli, Daund, Baramati, and Indapur. The length of the Mutha canal is 202 km and it irrigates about 62,146 ha of area. The left bank canal was filled up. It is not in use. Daund Nagarpalika also used the water of the Khadakwasla Reservoir for two months. Fifty Gram Panchayats also use the water. They sign an agreement with the Collector of Pune.

Interviewee: What is the cost of purchasing water from the Right Bank Canal?

Interviewee: The irrigation department charges Rs 2.64 for every 10,000 litres of untreated raw water.



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